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Propagation

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Editorial

A dream come true

India has one of the largest networks of Science Museums and Centres in the world under the umbrella of National Council of Science Museums (NCSM). Besides, there are many other science centres, planetariums and natural history museums outside the administrative control of NCSM. All these institutions are actively engaged across the country in science communication through various modes. A substantial quantum of professional knowledge and expertise thus being generated deserves public attention, review and recognition. Launching of *Propagation*, the half yearly peer reviewed journal on science communication, is a dream come true for us in supporting the innovative and creative works of Science Museum/Centre professionals and science communicators by providing them a platform to share, validate and get their works recognized.

The first issue of *Propagation* includes twelve papers contributed by professionals in the field of science communication, scientists, science historians and popular science writers. 'Science Museums - Science Centre - Science City - What Next?' traces the evolution of science museums with a futuristic projection, 'Diamond: A Wonderful and Lasting contribution of India to Mankind' tells us the story of diamond mining and diamond processing in India since ancient times and the science behind these operations, 'Science Communication and Social Upliftment' draws the intimate relation between science and society, while 'Impact of Science Museums & Centres' reasserts the role of science centres in our society. Two important historical accounts which find place in this issue are 'Three Phases of Popularization of Science in Colonial Bengal' and 'Geomagnetic Studies in the 19th Century British India'. The paper 'Presenting Indian Science and Technology Heritage in Science Centres' reflects the efforts of the National Science Centre, Delhi to ensure easy understanding of this subject. Various activities of science centres and their exhibits form the subjects of the papers 'Captive breeding of Butterflies ...', 'Lightning wheels' and 'Communicating Multi-wavelength Astronomy ...', while the paper on 'Genomics' touches upon some important and contemporary issues. 'A tribute to Acharya Jagadis Chandra Bose', documents NCSM's activities on the occasion of his 150th Birth Anniversary.

We sincerely hope that the variety and richness of the contents of this issue will be of interest to readers. We welcome constructive suggestions for improvement and, of course, solicit contributions in the form of articles, studies, reviews, reports, short notes and letters on innovative concepts and important findings for publication in the future issues.

Jayanta Sthanapati
Chief Editor

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Science Museum - Science Centre - Science City - What Next ?

Saroj Ghose

Some people are fond of making doomsday prediction not as much as for pressing a panic button, but for bringing an issue to the centre of the stage. Back in 1998, James Bradburne presented a thesis 'that science centres as they are presently constituted are dinosaurs threatened with extinction in the not too distant future, and that science centres as major capital projects are white elephants which can only saddle governments with unrecoverable debts'[1]. Although Per-Edvin Persson[2] quickly joined the debate in the same journal predicting a rosy picture for science centres of tomorrow, several science centre enthusiasts started ringing bells and blowing whistles until ten years later, the issue was brought to the centre stage of AAM annual conference as well as the ECSITE 2008 conference, with a question: 'What is the Science Centre of 2020?' The session description for the ECSITE conference[3] stressed on the 'relationships between the public presentation of science and the academic and industrial research centers', because it was felt that 'typically characterized as attractions for children, many science centers are struggling to be relevant to an older, adult audience, while revising the economic model to remain sustainable and viable.' Field & Powell talked about 'public understanding of science versus public understanding of research'[4] while Larry Bell talked about 'engaging the public in technology policy'[5]. Some others underscored the need for *public engagement in science* through lectures, debates, one-to-one interaction with renowned scientists – all as a part of the activities of science centres. This line of thinking tends to suggest a paradigm shift from fostering creativity amongst the children to encouraging critical analysis by the adults.

Museum, Centre, City

None of these suggestions, however, necessitate any change in the character of a science centre as far as its exhibit contents are concerned. Everybody agrees that concept and philosophy of exhibits in a science centre differ considerably from those in a science museum, but do the exhibits in a science city differ in any way from those in a science centre? Unfortunately, this is still a fuzzy area, where a science city is often considered just a *magnum opus* science centre without any difference in the concept of exhibits. In that case the title of this article becomes a misnomer. On the other hand, if the exhibits in a science city could be developed with a different philosophy, more advanced than in a science centre, title would imply a transition from science museum to science centre to science city. If so, one would venture to think what could be the next to science city.

Science Museums are primarily exhibit-based institutions concentrating on collection, conservation, documentation and exhibition of historical artefacts. 'A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment'[6]. Initially science museums were set up with touch-me-not artefacts, encased in glass cabinets, projecting the scientific and technological heritage of a country or of the human civilisation. Slowly came up some science museums with additional push button operated active exhibits to demonstrate the basic principles of science and the functioning of a contrivance. Danilov has given an elaborate account of the development of science museums while dealing with the history of science centres[7].

Science Centres, inspired by the Exploratorium in San Francisco and Ontario Science Centre in Toronto, evolved as activity-oriented institutions with hands-on interactive exhibits, and organised activities, involving visitors in experimentation so that they discover science by themselves. On the one hand, exhibits could be developed to supplement formal education in schools, as well as for non-formal education of the public. On the other hand, exhibits could have broad-based social relevance for creating scientific temper in the community. Parallel to the exhibits, science centres organise extensive activities, both in-house and outreach, for schools and communities.

Most science centres in the world are restricted within the four walls with indoor exhibits, sometimes supplemented by outreach activities. India introduced the concept of science park with interactive outdoor exhibits, developed for the first time in Nehru Science Centre, Mumbai in 1979, and then in all science centers in India. Some science centers, notably in New York, St Louis and Israel followed the suit with remarkably attractive playground exhibits. In a science city, the indoor didactic exhibits of a science centre and outdoor playground exhibits of a science park could be integrated into a theme.

Science City, for the first time developed at Kolkata in 1997, is a step ahead of science centres in the following aspects:

1. In addition to hands-on exhibits of science centres, a science city introduces minds-on experience through immersive visualization and simulated situation, which are created to cross the barriers of space and time and to emotionally involve the visitors.

2. In doing so, a Science City combines the fantasy and excitement of an outdoor theme park with non-formal learning process of an indoor science centre. The whole science city is a single unified exhibit area with imaginative integration of indoor and outdoor exhibits.

3. A Science City is developed as a self-contained closed biome reflecting exemplary symbiosis between man and other life forms with a carefully designed nature park, its own water management, sewage treatment plant, solar power station, and entertainment areas. That is why it is called a City, complete by itself.

4. The new concept of integration of indoor and outdoor exhibits in a science city is more relevant in countries like India, where a low capital-intensive outdoor exhibit area provides maximum *edutainment* to the people during most part of the year.

Science City in India is therefore not just a giant science centre like the *Cite des Sciences et de l'Industrie* in Parc de la Villette in Paris. It is conceptually different, and more advanced than a science centre where mental function plays a dominant role.

Hands-on Exhibits, Minds-on Experience

In a science city we are differentiating 'minds-on' experience from 'hands-on' interactivity, although these two terms are uttered in the same breath. Similarly the words 'hands-on' and 'interactive' are freely, and wrongly, treated as synonymous. The conceptual difference between passive, active and interactive exhibits, as well as the difference between hands-on and minds-on have been discussed elaborately elsewhere[8]. In brief, it may be stated the passive exhibits are those which have a visual, and sometimes tactile, appeal but are non-working in nature like in a traditional museum. Active exhibits are those which are animated or made to work by a push button, to act in the same manner every time they are operated. Interactive exhibits are of two kinds – hands-on and minds-on. Hands-on exhibits are those which build up a dialogue between the visitors and inanimate exhibits, by operating in different manners and by throwing questions to visitors through such operations. Thus, hands-on exhibits have two criteria – multiplicity of option and two-way communication. Minds-on exhibits are those which *may or may not be* hands-on, which go through a discovery process by themselves or where they cross the barriers of space and time in a simulated situation or in immersive visualisation. The differences may be summed up in the following chart:

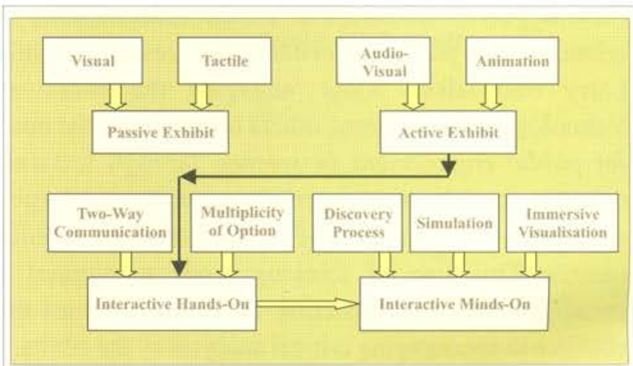

Fig 1: Passive, Active and Interactive exhibits

Let us take up an exhibit for example. This is an age-old exhibit on loop-the-loop demonstrating how a steel ball rolling down a channel negotiates a circular track without falling down. The weight of the ball is counteracted by the centrifugal force pushing it out. In order to save the ball from pilferage, the exhibit is encased in a glass cabinet and operated by a push button from outside. The exhibit is made more fascinating by passing the ball through nine loops in succession as developed by NCSM in 1987 (*fig 2*).

Fig 2: Demonstration of centrifugal force with two 9-loop exhibits placed back-to-back – an active exhibit behaving in the same manner every time it is operated (NCSM, 1987)

Operation by pressing a push button merely makes it active, and not interactive, because the exhibit behaves in the same manner whenever it is operated. It does not have multiplicity of option nor does it communicate with the visitors as they have no option to operate it in some other way. If we take out the exhibit for releasing the ball by hand, it instantly becomes interactive hands-on (*fig 3*). Visitors attempt to release the ball from

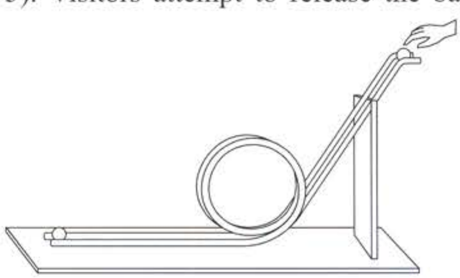

Fig 3. Interactive hands-on exhibit on centrifugal force, giving multiple options to visitors

different heights and discover the optimum height below which the ball will fail to negotiate the track. Then instead of releasing the ball from the top of the channel, somebody tries to push the ball from the lower end to see whether it negotiates the loop upwards (*fig 4*). He fails, doesn't matter how hard he pushes the

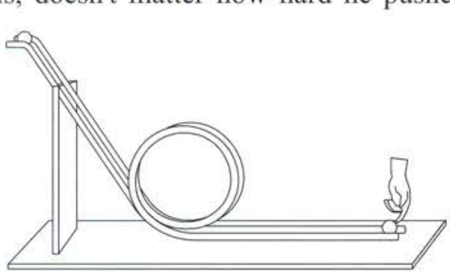

Fig 4. Visitors try to push the ball up the loop – an example of multiple options

ball up, but the moment he spins the ball while pushing up, the ball negotiates the loop. Thus, the exhibit now offers many options to the visitor.

Now we can make the exhibit interactive minds-on by using several table tennis balls, filled with a liquid, or partially filled with sand in different quantities, or with molten wax. We can use a straight channel for rolling down these balls to make it look simple but much more intriguing (*fig 5*). One ball rolls

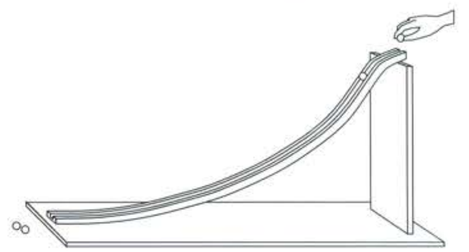

Fig 5: Interactive minds-on exhibit on rolling balls – simple but intriguing – giving rise to speculations and critical study

down with accelerated motion, the other with constant velocity, another does not roll but slides down, one ball leapfrogs down the channel, and the other simply refuses to move and stays tight in a spot. The exhibit looks totally confusing and its understanding demands application of mind in full extent.

The exhibit 'Mission to Mars' in Gujarat Science City (GCSC) is another minds-on exhibit combining a motion simulator with event simulators. Visitors ride a motion simulator for a space flight (*fig 6*) through the entire solar system and landing on the Mars on the

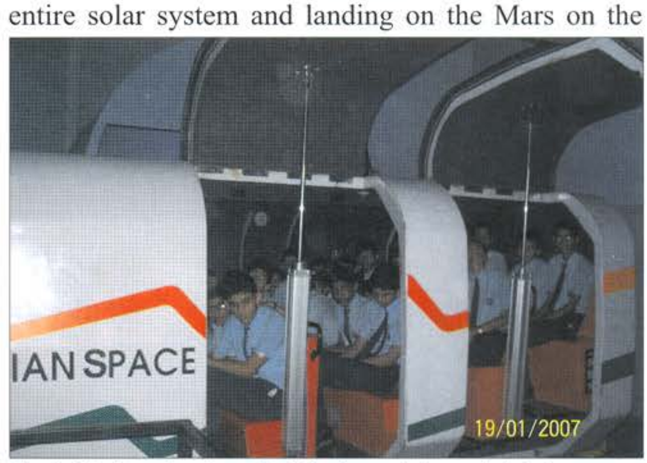

Fig 6. Motion simulator in Mission to Mars exhibit for simulating travel through the solar system (GCSC, 2008)

return journey with all associated thrills. After landing on Mars, they enter into a space laboratory set up on

Martian surface and perform experiments that astronauts are supposed to do for studying the geo-morphology and atmosphere of Mars, and searching for oxygen, water, and microbial life forms, if any (*fig 7*). This creates an emotive involvement through

Fig 7: Event simulation in Mission to Mars exhibit conducting experiments as if on the planet Mars (GCSC, 2008)

hands-on and minds-on experience, much more than the immersive visualization in a dome theatre.

Success Criteria for Future Development

The success of a science centre or science city depends on how effectively it can involve visitors, irrespective of their age, in activities for discovering science by themselves through their personal experience, sometimes in simulated situations, sometimes with immersive visualisation and most of the times in real-life real-time experimentation in open-

Fig 8. Children performing experiments in open-laboratory situation (GCSC, 2008)

laboratory environment (*fig 8*). Science centres do not believe in *Top Down* system of teaching-learning process which demands blind acceptance of authoritative explanation and information. Science Centres believe in *Bottom Up* system where the people have to build up their understanding of science through hands-on minds-on process. Science centres believe in the dictum of 'do it', then 'observe it', and finally 'discover it', rather than 'observe it' and 'accept it' without raising any question. Blind acceptance is a 'no-no' in interactive science centres. Bradburne summed up in his conclusion that 'the new learning platforms must stress the acquisition of new skills, not just information…. of course information is still indispensable, but it must be linked to the skills of finding, using and appropriating that information'[9]. This is precisely what the science centres are doing now and are meant to do.

Interactive science centres emphasize through its hands-on exhibits and activities, that science is not just some theories or mathematical equations or even some test tube experiments. Science is a logical thought process through which we can understand the laws of nature. The concept of science develops in a child's mind through observation of nature – the sunrise and sunset; the moon and stars in the night sky; the flowing river and turbulent ocean; the foliage, flowers, fruits and seeds; the life of birds, butterflies, bees and bugs; shapes and colours; and so on. In this observation a child uses all five senses to fathom the mysteries of nature. At a more matured age the young mind gets intrigued with laws of nature relating to sound, light, heat, and kinematics; electricity and magnetism, chemistry and chemical structures; mathematical logic; and the mysteries of the microworld of atoms and macroworld of outer space. With further maturity in thinking, visitors try to correlate the scientific phenomena with their understanding of life relating to environment, ecology, biotechnology, genetic engineering, information technology, and so on[10]. 'Topics such as global climate change, genetically modified organisms, information technology, and research into learning are not only of interest to the researcher, but affect everything from commonplace decisions such as whether or not to purchase genetically modified foods to policy debates on global warming to how we teach our children'[11].

What next ? Perish or Flourish?

Passive to active exhibits in science museums, active to interactive hands-on exhibits in science centres, and then hands-on to minds-on exhibits in science cities gradually brought us where we stand today. Now the question comes up – where do we go from here? What next? Are we going to follow the footsteps of white elephants and dinosaurs on way to extinction? Or do we have opportunities to transgress to a new domain? With further modified exhibits and activities ? Let us examine the activities first.

Concerns of future as expressed by various experts can be summed up in the questions raised by Robert Mac West : 'The museum industry is engaged in a series of very serious discussions and reflections on its future. What will the museum of the 21st Century be (we ask this question almost a decade into that century – a strong indication of collective uncertainty)? What will be the impact of Web 2.0 initiatives? How do museums respond to the enormous societal changes, ranging from considerations of authority figures to the rapidly-increasing personalization of desirable experiences? What economic and operational model(s) will museums have to adopt in order to be sustainable in the new environment?'[12] Undoubtedly these questions are heavily loaded for museums but also of generalised nature to include science centres as well. Science centre and science city are now acknowledged as a good platform for captivating the children, but what is lacking is adult participation. Science centres have to catch this large contingent through their activities.

Public Engagement in Science - get adults involved

In a lecture on 'Recent Trends in Science Centres' delivered in Science City, Kolkata, Per-Edvin Persson (Pele) pointed out that activities relating to *public understanding of science* are now yielding to *public engagement in science* with inclusive dialogue. Lectures, debates, interactive seminars, and face-the-scientist programs are organized by science centres to attract adult visitors (*fig 9*). Pele said that NGOs and special interest groups are urging science centres to *take a stand* on subjects like global warming, nuclear power, genetically modified food etc. During discussions, Pele clarified that it was not his personal opinion but a report on the current trends in science centres. Coming from a person who has enormous exposure to science centre activities all around the world, this observation deserves serious attention. Taking a stand on an issue means exerting authority on the Public, which is essentially a *Top Down* approach, in contravention with the accepted objectives of science centres. Also before taking a stand, science centres should first ascertain whether they have known the final words relating to such issues, after resolving all controversies emanating from social, economic and political vested interests. Opinions are split, with every camp claiming scientific evidence in their support. How much unambiguous are the scientific interpretations?

Fig 9. One-to-one meeting with scientists on subjects of topical interest – an example of people's engagement in science (GCSC, 2009)

Field & Powell quotes a source stating that 'in 1997, 63 percent of the public thought that the same scientific evidence can be interpreted to fit opposing views, 72 percent thought that scientific research is almost always affected by the values held by the researcher, and 40 percent thought that technology has become dangerous and unmanageable'[13]. And how much dependable is the media reporting on such acrimonious issues? Field & Powell quote *Science and Engineering Indicators 2000*, stating that 52 percent of journalists polled agreed with the statement that "the news media do not cover science because they are interested in instant answers and short-term results."

Science centres and science cities may not have disagreement that public understanding of science requires activities for public education and engagement. Instead of taking a stand, they should disseminate all necessary information and engage the public in interactive dialogues and hands-on experience with a *Bottom Up* approach so as to enable the public to take their own decision based on their exposure and experience derived in the science centre. Over the years science centres, around the world, have focused on hands-on learning experiences specially for the children, that are centered on exploratory learning and discovery. In the realm of technology, the focus has been on how things work. But public technology education is also about the impact of technology on the society, on which science centres need to organise sustained activities. In this regard, Larry Bell reports on his experience[14] : 'The Museum of Science in Boston has been experimenting with a variety of public engagement approaches designed to help visitors think and talk about the societal implications of nanotechnology. These approaches are generally interactive and two-way, allowing for the collection of data about what people think in addition to simply disseminating information about technology to them. This aspect raises ethical issues in itself. What, if anything, should museums do with information about the opinions expressed?'

White Elephant or Adorable Pet?

The future science centres and science cities have to take care of Bradburne's first caution that today's science centres are gobbling up enormous amount of public and private funds like white elephants, and are doomed to death. In support of his opinion, he cited high capital costs, high operating costs, and high maintenance and renewal costs. He looked convinced that 'given the exponential increase of the availability of new electronic media, such as home computers, CD-ROMs, and, soon, interactive television, coupled with their massive interconnection via the Internet, the informal learning which once was the preserve of the science centre can now be enjoyed at home or in other sites, thus rendering the science centre increasingly unwieldy, expensive, irrelevant and obsolete'[15].

Now in ten years after Bradburne's prediction, science centres have doubled in number from 1200 (in 1998) to 2400 (in 2008) in spite of occasional shut down of some science centres, here and there, for inefficient management. However, his second point regarding the availability of new computer technology at home deserves careful consideration. Subsequent to the success of the new breed of hands-on exhibits, developed and displayed in the Exploratorium, the USA was flooded with similar exhibits in 1980s, thanks to the Cooke Books brought out by the Exploratorium. By 1990 these exhibits became stereotype due to repetition and over usage. With the advent of handy communication technology with desktop computers, CD-ROM, and a large library of educational software and games, many science centres filled their halls with computer-aided exhibits which could converse and interact with visitors. In this context, Bradburne's caution of 1998 was very appropriate. But unlike dinosaurs, science centres again changed their approach with theme-based exhibits. By 1998 India's National Council of Science Museums had developed 25 science centres in addition to 2 industrial & technological museums and no two centres looked similar. Science centres, do not evolve around home-computer-technology any more.

It is true that science centres, and more so science cities, are instantly expensive to build but they are not ultimately expensive when one considers that the high running cost is completely off-set by large revenue. Museums and science centres, particularly at national and state levels in India, have been perennially dependent on government funding both for capital expenditure and operation & maintenance cost. A handful of private museums function with a low-key budget and low visitors attendance. In 1997 the Science City at Kolkata was developed with one-time government grant for capital expenditure with a plan that from day one after inauguration the government budget would be zero. This is the first self-reliant museum or science centre in the country, where the annual income-expenditure is fully balanced. Other science cities, which have come up during the last one decade, followed the suit where the operation and maintenance cost is met from the revenue, and government fund is used for the new development. In order to achieve self-reliance in O&M, several points had to be kept in mind:

1. ***Optimum Size:*** A small science centre which can be visited in two hours time is seldom self-sustained. A science city has to be developed to a size that a family is tempted to spend the whole day and have a satisfaction of getting the money's worth. A large science city, spread over a campus of 50 acres or more of outdoor exhibits in addition to the indoor exhibits, is also capable of holding a much larger size of visitors for longer period.
2. ***Fun, Fantasy, Excitement:*** *Edutainment* and not 'education' or 'entertainment' alone shall be the guiding principle for the exhibits and activities. Children are averse to education in parks, and adults feel 'science is not for me – but fun, yes'.
3. ***Blockbuster Exhibitions:*** People visit a cinema hall many a times, not for the building but for changing films. Science cities must have changing exhibits, preferably blockbuster, to attract repeat visits.
4. ***Sponsorship & Franchise:*** Private funding is plentifully available only if the client size is large. One million visitors or more is prerogative for attracting sponsorship and franchise for sustenance.

In free economy the guiding principle is *survival of the fittest* which sometimes turns out to be *survival of the fattest*. Whether it is the state or the private sponsor, nobody will dole away money just for nothing. No sensible person pays for white elephants. Funding will come for Science City only when agencies will be convinced of a good return, not always in terms of hard cash but in terms of achievements, which may be short term or ultimate. The ultimate achievement is *social transformation* for bettering the way of life.

Social Transformation

One definition of *Social Transformation* is the process by which an individual *alters* the socially ascribed social status of their parents into a socially achieved status for themselves. However another definition refers to large scale social change as in cultural reforms or transformations. The first occurs with the individual, the second with the social system. Social transformation can be achieved only by a *Bottom Up* process.

Science museums, science centres and science cities write their mission statements in different manners at different points of time, eg.:

- To collect, conserve, and exhibit artefacts with a view to instil national pride in country's rich scientific heritage
- To assimilate information relating to mutual interaction of science, technology and society with a view to develop self-confidence in nation building and disseminate the information through exhibits and activities
- To develop spirit of inquiry by encouraging curiosity and questioning processes, and to promote and support innovative ideas and activities
- To foster creative talent especially amongst the younger generation
- To promote scientific temper and eradicate superstition and obscurantism
- To supplement curriculum education in schools and colleges and to impart non-formal education on the community as a whole
- To encourage critical analysis of social, cultural, technological and natural environment and to inculcate an ability to identify the problems and work towards appropriate solution with scientific attitude for the welfare of mankind.

With all these statements, the ultimate mission needs to be 'social transformation' for bettering the life and values of the individuals and the social system. One has to remember Pele's oft-quoted statement: 'We are not in education business, nor in information business. We are in motivation business'. Can science cities of next generation motivate the people for social transformation? That would be the greatest success.

Dinosaurs or Adaptation?

Future science cities have to take note of Bradburne's second caution that 'Dinosaurs became

extinct for three fundamental reasons - rapid change in the climate, insufficient food to sustain their bulk, and increased competition from smaller, more flexible forms of life. In the same way, the life and death of the science centre as an institution is a question of ecology, and its demise just a matter of time'[16].

The change in climate comes from rapid changes in the societal structure, economic strategies, political institutions, and environmental scenario that every country (and the world as a whole) is going through. For their survival, science centres and science cities have to reschedule their priorities and realign their activities with the national priorities in the country they would be functioning.

For sufficient food to sustain, science cities shall have to explore the government sources, seek for corporate funding, and plan for visitor-focussed marketing[17]:

Exploring the Government Sources

- Reorienting the activities in line with national priorities
- Programs for the promotion of Cultural Heritage tourism
- Preparation of attractive packages for project proposals clearly identifying the objective, scope, target audience, expected outcome, finance and time schedule
- Approaching concerned government departments, central and state, instead of asking funds only from the nodal ministry
- Regular follow-up

Corporate Fund Raising

- Identifying the corporate bodies having business interest and/or ready market in a particular zone
- Preparation of attractive packages for project proposals preferably linking the activities with commercial interest of prospective sponsors, and highlighting the mileage that will be accrued to the sponsors
- Creating a one-to-one give-and-take sponsorship/partnership situation rather than asking for grants or donations
- Facility rental marketing

Visitor-focused Marketing

- Working out a reasonable entrance fee. structure and facilities like lucky draw during festivals
- Involvement of the local community in museum's programs
- Organisation of special events for different ethnic groups or for different celebrations.
- Celebration of birthday parties
- Creating a good environment for a profitable restaurant/snack bar, souvenir shop etc.

The most serious challenge comes from competition with other forms of entertainment. For science cities, the competition primarily comes from theme parks, packed with adventure, thrill and excitement. In a typical park atmosphere, theme parks offer opportunities for uncontrolled jumping and thumping all around for children, joy rides of all kinds for children and adults, and even quiet places on waterside with good food for elderly accompanying persons. Theme Park is a place of enjoyment for one and all. It seems a bit difficult for science centres with limited indoor facilities and education-loaded exhibits to compete with the adventures of theme parks, but science cities stand a much better chance to compete with their comparable outdoor facilities, immersive visualization, motion simulators and similar other exciting exhibits. What next? An even greater excitement with a strong foundation of science? That would be forthcoming.

Another challenge is the adaption to rapid changes in communication technology. Science museums and science centres passed through Computers 186 to 486, then P1 to P4 and onwards, a few hundred KB of memory to several hundred GBs, from DOS to Windows of various forms, from CD-ROM to DVD and interactive computer multi-media, sound-light-video synchronization, robotics (*fig 10*), animatronics, virtual reality (*fig 11*), more and more advanced types of immersive visualization, 4-D or 6-D theatre and what not. Additional capital investment brings in additional revenues to off-set the O&M cost.

Fig 10. Robotic dinosaurs in the Science City at Kolkata (1995)

Fig 11. Going back to 1947 to witness Jawaharlal Nehru delivering his Tryst with Destiny speech (Parliament Museum, Delhi, 2006) – animatronics with virtual reality

Bradburne evidently underestimated the capability of science centres to adapt. The question now comes: if science museums, science centres and science cities constitute three generations of activities, what shall be the next in fourth generation? What is our dream?

Dream Science

Jules Verne had a dream of 20,000 Leagues Under the Sea. The dream materialized in submarines.

Martin Luther King (Jr) had a dream of social equality. The dream materialized with the election of a black President for the USA.

APJ Abdul Kalam have a belief that "Great dreams of great dreamers are always transcended."

One has to have a dream of ***Dream Science*** after the present form of Science city.

Dream Science shall be a step ahead of Science City with stress on *Imagination* in all minds-on presentation. In addition to development of advanced generation of minds-on exhibits in open-laboratory situation, the fourth generation institution of Dream Science shall be futuristic to kindle imagination for things-to-come with exhibits and activities similar to the list below, which is just indicative and not exhaustive:

- Minds-on exhibit with motion simulation for undertaking inter-galactic travel in the so-called hyperspace suggesting multi-dimensional universe
- Animated 4-D/6-D theatre taking the visitors to the time of Big Bang and the *first three minutes* of the expanding universe
- Space tunnel with animated Large Hadron Collider
- Creating a situation for experiencing zero-gravity life in outer space and Moon Walk
- Virtual Reality projection on evolution of life
- Immersive visualization and event simulation on life and civilization in outer space
- Interactive activity for creating life in a laboratory, starting from inorganic matters
- Interactive laboratory for gene manipulation, gene therapy and genetic engineering
- Animatronics presentation of landmark inventions in human civilisation
- Creation of a robotic ideal village with *appropriate technology*
- Living inside huge bio-domes, experiencing a Mars colony by *terraforming* of Mars
- Live shows of performing arts on themes of science, technology and environment
- Walk through faithfully recreated eco zones with animatronics of biodiversity
- Conversion of typical theme park rides to science-based edutainment
- Live audio-video channels with BARC, ISRO, DRDO, CSIR labs, medical centres
- Live audio-video interaction with inspiring scientists of the country
- Regular interactive programs for public engagement in science
- Advanced activities for fostering creativity in the young minds
- And so on

The real strength of Dream Science shall be something which dinosaurs did not have. Dream Science shall transcend from education, information, adventure and knowledge to *imagination*. In the words of Einstein: 'Imagination is more important than knowledge. Knowledge is limited. Imagination encircles the world.'

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Dr. Saroj Ghose, Padma Bhushan, the first Director General of the National Council of Science Museums in India, former President of the International Council of Museums in Paris, and Fellow Member of the Association of Science-Technology Centres in USA, spent more than 50 years of his life in developing more than 30 new science museums, science centres, science cities and high-tech story-telling museums in India and abroad.

Diamond: A Wonderful and Lasting Contribution of India to Mankind

Krishan Lal

Abstract

Gems have been objects of fascination and value for humanity since pre-historic times. Major civilizations like India had developed techniques for mining and processing, particularly for ornamental purposes. It is well established internationally that Indians were the first to identify, mine and process diamonds and study their properties. This paper describes how diamonds were being referred to in the famous epics Ramayana and Mahabharata, Purana -Srimadbhagavat and teachings of the Buddha. Developments in modern science have enabled understanding of the science of materials as well as that of diamond and other gems. The landmark experiments in determination of composition of diamond have been described. The development of basic crystallographic principles and the structure of diamond crystals have been discussed.

Introduction

Mankind has been fascinated by the beauty and exceptional properties of naturally occurring gems since times immemorial. These prominently include diamonds, sapphire and ruby. Diamond occupies the highest position among gems due to its exceptional physical and chemical properties and aesthetic appeal. It is now well accepted internationally that Indians were the first to discover diamond and understand its various properties and use it in ornaments and other applications. Special techniques were developed in India to process the diamonds for jewellery. Some of these techniques, particularly those involving cleavage along crystallographic planes are amazingly prevalent even today. Presently, diamond has found wide spread applications in several sectors of human activity. Due to their exceptional mechanical, electrical, optical and thermal properties they have great potential for fabrication of solid state devices. Diamond films have been a subject of very intense investigations and have several applications. One of the most widely used applications of diamonds is in cutting tools. The present day construction industry in India employs diamond cutting tools in large scale for preparing slabs of stones like granite and marble.

Our understanding of the science of crystals is relatively new. Several concepts about the chemical composition and structure of materials have evolved during the last 300 years or so. If one follows the history of developments in our understanding of diamond crystals, one can learn as to how our understanding of materials has progressed during the modern science era.

In this paper, we shall describe how in India, mention of diamond is found in some of the most well-known scriptures. Major landmarks in the development of our knowledge about diamonds are also described.

Diamonds: A Great Contribution of India

Several important Indian classics such as Ramayana and Mahabharata have explicit references to diamonds. If one looks at the period of these texts, one can infer about the state of knowledge about diamonds and the extent of their usage in society. In this paper, the author is reproducing specific explicit references to diamonds based on own personal study. There may be many other records on the same subject. It is well-known that Valmiki's Ramayana is one of the oldest classics of mankind, and particularly of the Sanskrit language. It describes the story of Lord Rama. Lord Rama has deeply influenced the life and culture of the people in the entire South Asia, South East Asia and parts of Central Asia. The world famous temples of Angkor Wat in Cambodia are a great testimony to this fact. Besides India, traditional dances in Indonesia, Thailand and many other countries in the South East Asia are based on Ramayana. In the Uttarkand of Ramayana, the great Sage Valmiki describes the return of Lord Rama to Ayodhya, the capital city of his dynasty, after destroying the powerful Rakshas clan headed by the mighty and awe-inspiring King Ravana. Lord Rama was coroneted as the king and on this occasion he offered gifts to several of his commanders and supporters in the war against Ravana. Shloka 25 from Sarga 39 of Uttarkand is reproduced in the following:

एवमुक्तवा ददौ तेभ्यो भूषणानि यथार्हतः ।
वज्राणि च महार्हीणि सस्वजे नरर्षभ ।। 25 ।।

श्रीमद्वालमीकि कृत रामायण़ उत्तरकाण्ड़ सर्ग 39

The English translation by the author is as follows:

"Saying so the hero among men (Lord Rama) presented them (the commanders of the Vanar army), according to their respective status, several pieces of jewellery and precious DIAMONDS and embraced them."

Ramayana; Srimad Valmiki; Uttarkand, Sarga 39; Shloka 25.

This shows that the diamonds, even at that time, were coveted and precious and not so common, a

typical property of a gem stone. Perhaps these were fit only to be given to kings like Sugriva and great devotees like Hanuman and the newly coroneted king of Lanka, Vibhishana.

In Dwapar Yuga, according to Hindu understanding of this cycle of creation, great Sage Ved Vyasa created the classic Mahabharata, which is unmatched in view of its philosophical content, the narrative in Sanskrit poetry and the vast knowledge and also illustrations of human relationship. Here again, some explicit references to diamonds are found. Three shlokas from the Aadi Parva of Mahabharata are reproduced below.

वैशम्पायन उवाच

ततस्तु कृतदारेभ्यः पाण्डुभ्यः प्राहिणोद्धरिः ।

वैदूर्यमणिचित्राणि हैमान्याभरणानि च ।। 13 ।।

वासांसि च महार्हाणि नानादेशयानि माधवः।

खम्बलाजिन रत्नानि स्पर्शवन्ति शुभानि च ।। 14 ।।

शयनासनयानानि विविधानि महान्ति च ।

वैदूर्यवज्रचित्राणि शतशो भाजनानि च ।। 15 ।।

श्रीमहाभारते आदिपर्वणि वैवाहिकपर्वणि अष्टनवत्यधिक शततमोऽध्याय: ।।

"Vaishampayan says, O Janmejaya! Thereafter Lord Shri Krishna sent as presents for Pandavas after their wedding ceremony was over, several gold ornaments studded with Vaidooryamani, very expensive clothes, very soft blankets manufactured in several different countries, deer-skins, beautiful precious stones, beds, sitting couches, big vehicles of different types and hundreds of utensils, which were beautified with Vaidooryamani crystals and diamonds."

Shrimahabharat, Aadi Parva, Vivahikparva, Chapter 108, Shlokas 13-15.

The background of these shlokas is as follows: King Drupad had invited kings and princes for the Swayamvara (selection of the bridegroom by the bride) of his beautiful daughter princess Draupadi. He had declared that Draupadi will marry the prince/king who will pierce with his arrow the eye of a rotating fish fixed above a rotating wheel. The candidate had to shoot his arrow while looking at the image of the fish in a container filled with oil and placed on the ground. All the assembled nobility failed to accomplish the task and finally it was the mighty archer Arjuna, disguised as a commoner who fulfilled the condition of marriage. Arjuna was third of the five Pandava brothers. This followed with the formal wedding between Pandava brothers with Draupadi as is well-known. It may be mentioned that the Pandavas were in hiding before this wedding and King Drupad, though bound by his vow to marry Draupadi to a person who will fulfill the condition mentioned above, was worried about the family background of the ascetically dressed Arjuna. Of course, after knowing the reality, he was very happy and all relatives including King Dhritrashtra, Pandavas' uncle at Hastinapur and Lord Krishna in Dwarka were informed about the wedding. As is custom, several gifts were given to the newly-weds. These three shlokas describe the gifts given by Lord Krishna. As is well known, the classic is being narrated by Rishi Vaishampayana to King Janmejaya, the great grandson of Arjuna. In these shlokas, Rishi Vaishampayana has described in detail the gifts sent by Lord Krishna. These included hundreds of utensils studded with diamonds and other precious crystals. This shows that in this period, the availability of diamonds was on a much larger scale than that available in the period of Ramayana.

The tenth Skandha of Shrimadbhagavat Purana is devoted to the life of Lord Krishna. The ambience at the time of his birth is described in the following beautiful shloka, which also describes celebration of the event by Nature:

दिशः प्रसेदुर्गगनं निर्मलोडुगणोदयम् ।
मही मंगलभूयिष्ठपुरग्रामव्रजाकरा ।। 2 ।।

श्रीमद्भागवतपुराण अ० 3 दशम स्कंध

"All the directions were clear and happy. The stars were twinkling in blemishless sky. On the earth, the big cities, the small villages, settlements of Ahirs and the mines of diamond etc were bountiful."

Shrimadbhagavat Purana, Shloka 2, Chapter 3, The Tenth Skandha

Closer to our time, we find beautiful reference to diamond during the life time of Lord Buddha about 2500 years ago. In one of his sermons, he had mentioned (in Pali):

अत्तना व कतं पापं अत्तजं अत्तसंभवं ।
अभिमन्थति दुम्मेधं वजिरं वस्ममय मणि ।। 5 ।।

"The evil done by himself, originated by himself, emanating from him crushes the fool as the diamond crushes a hard gem."

The Ego, Commentaries on The Dhammapada
The Mother, Sri Aurobindo Ashram, Pondichery, 1995 (II[nd] impression)

This couplet has two parts. The first half describes an ethical and spiritual truth about the futility and dangerous consequences of evil and the other part is a fundamental principle of materials science namely, "the diamond crushes a hard gem". The spiritual and the materials science principles are as true today as these were at the time of the Buddha. Diamond remains the hardest material known to man. It may be remarked that this sermon was delivered to the common people of India including the farmers, the traders and others. It shows that at that time it was common knowledge that diamond can crush even the hard gem meaning that it is the hardest material. Therefore, we see that information and knowledge about diamond was at high level about 2500 years ago. In the Arthshastra authored by Kautilaya also, there is a chapter dealing with diamonds.

In Europe, the knowledge about diamonds is comparatively recent. However, a few hundred years ago, it was common knowledge there that diamonds were mined and processed in India. Till recent times, Indian diamonds were in great demand in Europe. In fact, it is often said that when deposits of diamonds were found in South America, they were first brought to Goa and then re-exported to Europe. One of the often quoted record about diamonds and their origin being in India is Sir John Mandeville's book 'Travels' published in 1360. In this book it is mentioned,

..."Diamonds grow together, male and female, and are nourished by the evening dew. They bring forth small children, which grow all through the year. Diamonds tend to be found in India in the hills where the gold mines are, and often the diamonds are found embedded in a mass of gold. Keep a diamond with a piece of rock, water it with May dew and it will grow large. Wear it on the left side and it will endow manhood, keep the limbs whole, give victory over enemies, preserve from wicked spirits and even turn witchcraft away and send it back to the bewitcher. A diamond will sweat if poison is brought near it. ... Yet, in spite of all its virtues, a diamond can be corrupted by the shortcomings of the person wearing it; it can lose its powers and then be of little use."...

Sir John Mandeville's Travels (1360)

Diamond as a Highly Coveted Gem Stone

A gemstone is expected to be endowed with several important attributes. In general, there are four cardinal values of gem stones. These are:

(I) beauty;
(ii) durability;
(iii) rarity; and
(iv) reputation and publicity.

The beauty of gem stones lies in its colours and brilliance that can be enhanced by suitable cutting and polishing. The colours are mostly related with impurities present in gems. For example, chromium in alumina makes it ruby. Similarly, sapphire (α- alumina though transparent and colourless) also exhibited colours in presence of other impurities. In the case of diamonds also, impurities produce bluish or brownish and other colours. Durability is a very important attribute of a gem stone. All ornaments are exposed to the atmospheric gases which can corrode gems if they react with these gases. Also, dust particles are present in the air which, subject all materials to abrasion.The dust contains large fraction of hard particles like those of quartz. A gem stone should be quite inert to the atmosphere and its hardness should be at higher than that of quartz so that these are not subjected to abrasion. Rarity is important as it defines the cost of gem stones. It is well known that big commercial establishments involved in marketing of precious gem stones like diamonds are very keen to ensure that the availability remains limited so that the cost is reasonably high. For example, after the political changes in Russia, there was a possibility of Russian diamonds coming to the international market in a big way. The international commercial giants have entered into agreements with Russian establishment to restrict the volume of sale of Russian diamonds. It is quite similar to what the Organization of Petroleum Exporting Countries (OPEC) does to control the prices of oil in the international market. The reputation and publicity enhance the value of gem stones. Some of these are myths and legends. For example, there are several legends around many diamonds. Of course, the trends in the fashion world also decide the value of different gems.

Some of the famous diamonds

As mentioned above, diamonds have been associated deeply with India. Several diamonds of Indian origin figure prominently among the world famous diamonds. The most well known among these is the Koh-i-Noor, a white diamond of Indian origin, weighing 105.6 carat. It is associated with many myths and legends. Its masters have been changing with time. The last Indian ruler to possess it was Maharaja Ranjit Singh. However, it was taken from his son Maharaja Duleep Singh and presented to Queen Victoria, after the British conquered Punjab and deported some of the

family members of Maharaja Ranjit Singh to Britain. It is now a part of the Crown of Queen Elizabeth, the Queen Mother. Following are the other prominent diamonds of Indian origin:

1. The Orlov, weighing ~190 carat, Indian mogul cut, supposed to have been part of a Hindu statue, presently it is in the Kremlin;
2. The Shah Diamond of Indian origin (~1450), yellow in colour;
3. The Nepal Diamond, 79.41 carats, pear-shaped brilliant, origin believed to be Golconda mines;
4. The Akbar Shah, roughly pear-shaped outline, perhaps a part of original peacock throne;
5. The Agra Diamond, 28 carats, stellar brilliant;
6. The Briolette of India, ~90 carats, one of the oldest diamonds;
7. The Moon of Baroda, ~24 carats; and
8. The Nizam Diamond, a 340 carat diamond.

Historically, the largest known gem quality diamond is The Cullinan Diamond, mined in 1905 in South Africa. It weighed 3107 carats approximately. Later, it was cut into 105 diamonds including the Great Star of Africa, the Cullinan I weighing ~530 carats and the Lesser Star of Africa, the Cullinan II ~317 carats. Now, both of these are part of the British Royal Treasure. The Oppenheimer Diamond is one of the largest gem-quality uncut diamonds in the world and weighs about 254 carats.

Scientific Understanding of Diamond

Chemical composition

Our knowledge base about diamond is very large but of comparatively recent origin. It is a wonderful material with many unique properties. It is the hardest material and has very high value of refractive index. Its thermal conductivity is nearly six times that of silver. However, it is an insulating material with large band gap. This is a major contradiction. Normally, electrically insulating materials are also bad conductors of heat. Jewellers often use thermal conductivity as a way of distinguishing a genuine diamond from a fake one. In modern day understanding of any material, the most basic parameters that define it are its chemical composition and crystallographic structure. The chemical composition of diamond was a problem of considerable scientific interest for a long time leading to several investigations. Some of the top scientists had tried to study this aspect of diamond. For example, the great scientist, Isaac Newton while investigating optical properties of materials was highly impressed with the high value of refractive index of diamond. His experience with optical properties of materials prompted him to remark in 1640 that diamond is ..."probably unctuous substance coagulated"... . However, this observation did not throw any light on the composition of diamond except the assumption that it may be a kind of dense oily substance.

The real breakthrough about the composition of diamond was achieved in an experiment conducted by two Italian scientists, G. Averani and C. A. Torgioni in Florence in 1694. They focused sunlight by using a telescope on few pieces of diamond. To their surprise, they found that nothing was left of the diamonds after irradiation with the intense beam of sun light. These had "evaporated". This was a very significant observation. The real consequence of this experiment was established by the famous French scientist, Antoine-Laurent Lavoisier, well-known for his work on combustion. Lavoisier repeated the experiment performed by Averani and Torgioni at Louvre (Paris). He made a significant improvement in the experimental set up by enclosing the diamond specimens in a closed bell jar. As expected the diamonds evaporated when sunlight was focused on these. However, Lavoisier was shocked and surprised to find that the end product of this experiment left in the bell jar was carbon dioxide. This was most surprising as CO_2 was also obtained when charcoal was subjected to the same exposure to focused sunlight. This showed that diamonds are composed of carbon atoms like charcoal. Therefore, on chemical basis diamond $\equiv$ coal. It may also be interesting to note that earlier Lavoisier had mentioned that all crystals including diamonds were formed with water. This experiment fascinated many scientists including the well-known Chemist Humphrey Davy. Davy tried to focus sunlight on diamonds in Britain but did not succeed to evaporate the same. He travelled to Florence and repeated the experiment Averani and Torgioni did there, in 1814 and confirmed that exposure to intense sunlight led to combustion of diamonds. Therefore, he concluded that the result of this experiment is "nearly a solution of diamond in oxygen" and the resultant gas is carbon dioxide. It is important to mention that initially Davy had proposed that diamonds may be charcoal containing some important impurity as impurities in iron lead to formation of steel. In this matter, doubts were raised subsequently about the identity of atoms constituting charcoal and diamond. It was thought that perhaps these two materials may be composed of two different atoms having similar chemical properties like chromium and nickel, which have very similar chemical properties. In 1890, A. Krause performed

further experiments to resolve this issue. He burned diamonds in pure oxygen atmosphere and dissolved the resultant CO_2 in ammonia and mixed it with sodium hydroxide. He evaporated this solution and obtained crystals of sodium carbonate (Na_2CO_3). He repeated the whole process with charcoal in place of diamonds and compared the properties of Na_2Co_3 crystals obtained in the two experiments. The crystals prepared from diamond and charcoal as starting materials were found to be identical. This led to global acceptance of the fact that diamonds like graphite and charcoal are composed of carbon atoms. It may be noted that it was only about 120 years ago that this was established.

Structure of Diamond

One of the basic questions to be answered by scientists was as to why physical properties of diamond and graphite or charcoal are so different even though these are composed of the same carbon atoms. Diamond is the hardest of all materials whereas graphite is among the softest materials. We all use pencils for writing and the writing "Lead" is generally made from graphite. When we write on a sheet of paper with a pencil, millions of carbon atoms are transferred from the lead to the paper. This conceptual difficulty was due to the fact that all properties could not be understood on the basis of chemical composition of materials alone. One had also to understand the arrangement of atoms, ions or molecules in the materials at the atomic level to unravel this mystery.

The study of minerals and other crystals had been an active area of study for the last few hundred years. The symmetry of naturally occurring crystals has fascinated mankind in general and scientists in particular. The empirical studies of naturally occurring crystals showed that in natural crystals of a given material, the interfacial angles were found to be always constant. Take for example, the case of the widely available quartz crystals (Fig. 1). The angle between

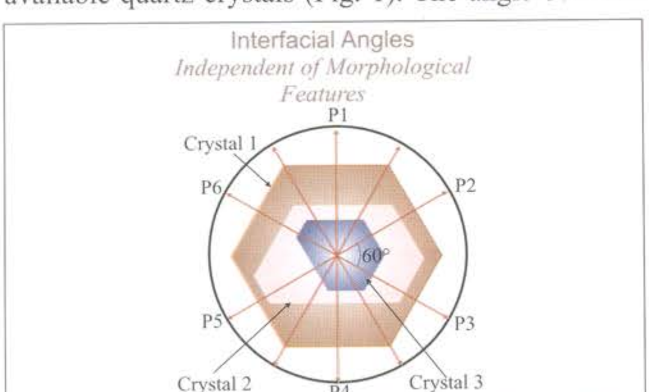


Fig. 1. Cross-section of three quartz crystals along basal plane. The angles between the adjoining plane faces P1 to P6 are 60° even though their lengths may be different

adjoining faces of quartz crystals is 60° and if we rotate the crystal by 60 around an axis which is parallel to these faces, you will get an indistinguishable position of the crystals in terms of interfacial angles. However, one has to remember that the linear dimensions of different faces may be different as shown in Fig. 1. These studies lead to the *Law of Constancy of Interfacial Angles*. Further investigations showed that one can conceive an ultimate smallest unit of a crystal named as a 'unit cell'. All crystals can be considered as stacks of unit cells like bricks are used to build big civil structures like homes. Since the unit cell is a three dimensional body as shown in Fig. 2, it can be uniquely described by the dimensions of three unit vectors

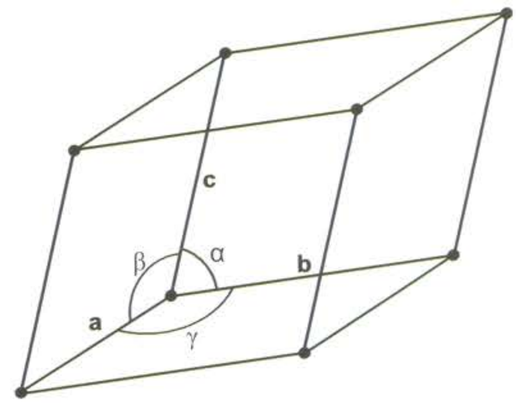


Fig. 2 A unit cell characterized by unit vectors **a**, **b** and **c** and angles α, β, and γ between the unit vectors as shown.

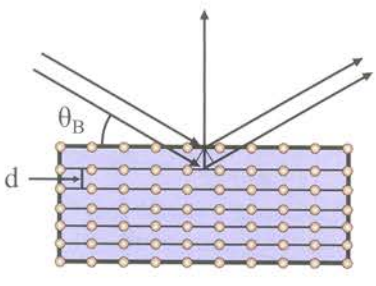
termed as **a**, **b** and **c** and the angles between these three vectors which are termed as α (angle between **b** and **c**), β (angle between **c** and **a**), γ (angle between **a** and **b**) as shown in Fig. 2. On the basis of the relative proportions of **a**, **b** and **c** and the values of α, β and γ, the following seven crystal systems were identified: triclinic, monoclinic, orthorhombic, tetragonal, trigonal (rhombohedral), hexagonal and cubic. The most symmetric among them is a cubic unit cell in which $a = b = c$ and $\alpha = \beta = \gamma = 90°$. The least symmetric unit cell is triclinic in which $a \neq b \neq c$ and $\alpha \neq \beta \neq \gamma$. By considering the centres of the faces and the body of unit cells these yield 14 Bravais lattices. Further investigation into possible symmetries led to 32 elements of symmetry like the axis of rotation and symmetry plains. In all, 32 point groups had been established. When the translational symmetry was introduced, in all 230 space groups were defined. This happened only about 120 years ago.

A major revolution in science took place with the discovery of diffraction of X-rays. As is well known, in 1895, Roentgen discovered X-rays and in 1912, Max von Laue together with Walter Friedrich and Paul Knipping discovered diffraction of X-ray from crystals. This was a major development with far

reaching consequences. It directly showed that inside the crystals, atoms, ions and molecules are arranged at a periodic network and X-rays can be used to study their arrangements. In 1913, the father and son team of W. L. Bragg and W. H. Bragg used X-ray diffraction to determine interplanar spacings in crystals and determined the size of unit cells. Braggs used the arrangement schematically shown in Fig. 3. By using a simple equation given below, the interplanar spacing d in Å units could be determined by measuring angles θ, which are in arc degrees:

$$2d\sin\theta = n\lambda \qquad [1]$$

Here, θ is the angle made by the incident X-ray beam with the crystal surface (Fig. 3), λ is the wavelength of the X-ray beam and n is an integer.



$$2\,d\,\sin\theta_B = n\,\lambda$$

Fig. 3. The Bragg geometry for study of diffraction of X-rays from crystals.

Braggs also investigated diamonds and in 1913 they determined their structure. Since then, techniques for determination of structures of crystals have been developed greatly. By structure, we determine the size of unit cell and fix coordinates of constituent atoms or molecules in the unit cell. The same principles are being used now to reveal the structure of proteins and other macromolecules and in design of drugs to cure serious diseases. It is now well established that a diamond lattice consists of two interpenetrating face centered cubic lattices which are displaced with respect to each other by ¼th of the lattice spacing in each direction. A face centered cubic (FCC) unit cell contains four atoms, one at the corner (actually eight corners but each shared by eight cubes) and three at face centres (actually six at the centres of six faces of a cube but each shared by two faces of adjoining cubes). Their fractional positions in the unit cell are: 0, 0, 0; ½, ½, 0; ½, 0, ½; 0, ½, ½. Therefore, the diamond lattice contains 8 atoms in the unit cell and the fractional positions of carbon atoms are as follows:

0,0,0; ½, ½, 0; ½, 0, ½; 0, ½, ½; ¼, ¼, ¼; ¾, ¾, ¼; ¼, ¾, ¾; ¼, ¾, ¾.

The value of lattice parameter a of diamond is 3.567Å.

It may be mentioned that initially there was a great interest about the primary symmetry in diamond crystal which governed its structure. Some scientists proposed that diamond is without a centre of symmetry and can therefore exhibit the phenomenon of pyro-electricity. Many others proposed that it does not have a centre of symmetry. Another serious issue was to understand bonding between carbon atoms in diamond crystals. The atomic positions of carbon atoms in the unit cell showed that these are tetrahedrally coordinated. However, the Bohr model of atoms would expect that the electronic occupancy of different shells should be: $1s^2$, $2s^2$ and $2p^2$. The outer shell should have only two electrons and therefore each carbon atom should be bonded to two carbon atoms only. This also led to difficulties in understanding the bonding in molecules like methane CH_4. However, the wave mechanical understanding of bonds in crystals led to the concept of hybridization of electronic orbitals. It was in 1928, that sp^3 hybridization of carbon-carbon bonds was understood. With this, the tetrahedral covalent bonding of carbon atoms in diamond was understood. The strong covalent bond explains the very high hardness of diamond crystals.

It may be mentioned that diamonds have very interesting absorption features in the infrared (IR) region. It shows a strong absorption band at ~8 μm wavelength. Initially in mineralogical studies, this IR absorption band was used to identify diamonds. Later, it was found that in some of the diamonds, there was no IR absorption at ~8 μm. On this basis, diamond had been divided into two categories. Most of the diamonds exhibit IR absorption ~8 μm and had been named as type I variety, while others, which are nearly transparent at ~8 μm have been classified as type II. R. Robertson and J. Fox had made detailed investigations in this field in 1930s. The basic problem was as to explain why most of the diamonds exhibited a prominent absorption band at ~8 μm, while a few of them did not do so. Sir C.V. Raman had keen interest in study of diamond crystals and he tried to explain this difference on the basis of different structures of diamonds. In X-ray diffraction patterns also diamonds showed very peculiar spots. Raman proposed that the difference in the infrared spectra of type I and type II diamonds was due to their structures. He further proposed that X-ray findings leave the question of tetrahedral and octahedral symmetry entirely open. He proposed that type I diamonds are tetrahedral type with a centre of symmetry. However, X-ray diffraction investigations particularly by Kathleen Lonsdale and others reported the presence of a weak 2 2 2 reflection in type I diamond crystals, which is not expected in the diamond lattice. Lonsdale stressed that it conclusively proves that the structure is not tetrahedral. These

different type of views were finally resolved by experiments performed in Bell Laboratories in USA by W. Kaiser and W.L. Bond in 1959. They performed an interesting experiment, in some way similar to the experiments of Lavoisier. They heated diamonds inside a vacuum chamber at high temperature and allowed these to evaporate. The gases produced in these experiments were analyzed by sensitive mass spectrometric analysis. It was found that type I diamonds contained appreciable quantity of nitrogen whereas type II diamonds were nearly free of nitrogen. This showed that the presence or absence of nitrogen was responsible for different IR spectra of type I and type II diamonds. Subsequently, other impurities in diamonds have also been observed. Recently, in author's laboratory, several high resolution X-ray diffraction experiments have been performed on type I and type II diamonds obtained on loan from the well known collection of Professor C.V. Raman. Interestingly, there were significant differences in intensities of X-ray diffraction peaks of the two types of diamonds.

Concluding Remarks

In the overview given above, the author has tried to show that diamond remains a very interesting material for scientific investigations. Intense investigations have been made to produce thin films of diamonds or diamond like carbon films for several optical and industrial applications. Fairly large diamond crystals have been produced in the laboratories by subjecting graphite to high pressures and high temperatures in the presence of catalysts like nickel and cobalt. Many industries, including some in India are engaged in production of synthetic diamonds for various applications.

In this paper, the author has focused on the scientific understanding of diamond and described as to how it was valued and used in the ancient times. There is also a very wide spread usage of diamond and other gem stones for affecting the fortunes of individuals. This is a big industry. However, the author is not aware of any scientific basis of these applications.

Dr. Krishan Lal, an eminent physicist, retired as the Director, National Physical Laboratory, New Delhi. He is INSA Senior Scientist and Chairman of the Research Advisory Board of CRTL (NCSM).

Science Communication and Social Upliftment

Narender K. Sehgal

Abstract

We examine how science communication can help make more and more people scientifically literate and aware. Also, to keep them that way, i.e. scientifically aware and literate, science communication needs to be continual, persistent and sustained. Social upliftment, in very simple terms, means turning 'have-nots' into 'haves'. We will see that the only way science communication can help do that is by enabling, empowering and motivating the have-nots into putting in the required effort to lift themselves, out of their present condition, into the category of haves – and having done that, help others to do the same, and never to allow themselves to revert to their earlier condition.

Science communication is a term that covers a lot of ground, in terms of what it can do directly for people, and in what it can help us achieve indirectly. Social upliftment falls in the latter category – unless an increase in scientific literacy of the general public, itself, is considered as one among essential parameters that characterize social upliftment. As one who has been for long advocating and working for promoting scientific literacy as an essential trait for every self-respecting citizen of India (and of this world), I would certainly include it high in the list of essentials for social upliftment.

Scientific Literacy and Scientific Awareness

Science communication is done in a variety of ways, and for a variety of purposes and audiences, employing a whole range of media and means. For purposes of this piece, however, we will restrict ourselves to science communication of a particular kind, aimed at masses of common people. This would imply that we are talking about 'science' and scientific laws and principles at work all around us – at home, at place of work, and in between – in our everyday lives. Incidentally, the word 'science' is used here in its widest meaning and popular parlance, to include its methodology, culture, applications and technology as relevant. In other words, we are referring to 'science communication' of the type that would promote scientific literacy and ever-increasing understanding, awareness and grasp of scientific aspects of issues and questions that concern and confront us continually in our daily lives. To elaborate, let us see what this kind of

(i) It can raise, or create, awareness about an issue, or a useful practice; against a harmful practice, tradition, or a superstition.

(ii) It can empower people with information, practical knowledge, explanations of things unknown, useful skills, etc., for generating or increasing income; or for more efficient use of available resources.

(iii) It can help demystify so-called miracles performed by self-styled godmen, technologies, or things like uncommon natural phenomenon, diseases etc. that generate needless awe, fear, or apprehension.

(iv) It can help prepare people to handle man-made or natural disasters, and their after-effects better.

(v) It can help in safer and more efficient use, handling, and maintenance of modern-day gadgets, implements and devices.

(vi) It can help teach people to make better and more informed purchase decisions to get the most out of their money, while buying things for long-term use.

(vii) It can help people become more quantitative and do simple quantitative analysis to help in their investments of savings for better future for their children and themselves.

(viii) It can encourage people to adopt logical thinking and reasoning, more and more often in whatever they do, with real life examples, which get the message home effectively.

(ix) It can help raise levels of scientific literacy among people in general, which in turn could have a number of beneficial effects in many ways.

(x) It can make people aware of all the good potential of developments taking place in science, and of those in the pipeline. Equally, it can make and keep them aware of harmful effects resulting from misuse and abuse of technology already taking place, and of similar future possibilities.

A good number of government institutions, non-government and voluntary organizations are involved in science communication in the country. Of these, only a handful of central government institutions are devoted solely to science communication, whereas quite a few others have 'science communication' only as part of their much larger mandates. Prominent ones in the former category are NCSTC (the National Council for Science & Technology Communication, DST), New Delhi, NCSM (the National Council of Science Museums, Ministry of Culture, Government of India), Kolkata, and Vigyan Prasar (an autonomous institution under the Department of Science & Technology, Government of India), New Delhi. There are a good many in the latter category, both at the Centre and State levels: NCERT (the National Council of Educational Research and Training, MHRD, New Delhi), NISTADS (the National Institute of Science, Technology & Development Studies) and NISCAIR (National Institute of Science Communication & Information Resources) of the CSIR (the Council of Scientific & Industrial Research, Ministry of Science and Technology, New Delhi), and the State Science and Technology (S&T) Councils in almost every State and Union Territory. In addition, there are "Science Cities" – really, very large Science Centres – in West Bengal at Kolkata, in Punjab near Jalandhar (on the Kapurthala Road), and in Gujarat, near Ahmedabad, run either by the respective State S&T Councils or under some other State set up especially created for the purpose. We will come to the non-governmental and voluntary sector organizations a little later.

The only reason these institutions and organizations find mention here is because, together with NGOs and voluntary organizations active in this area, they form the back-bone of the entire science communication edifice in the country. Barring exceptions, the overall impact of science communication, on the Indian population, can be likened to a few puffs of air reaching individuals from a small number of ceiling fans of a large, packed auditorium. In other words, aside from a small number of honourable exceptions, most of the science communication programmes on offer are generally meant to spread awareness on issues or topics of current, or perennial interest, on an upcoming celestial event – like a total solar eclipse, a lunar eclipse, coming of a periodically visible comet, clusters of meteor showers, occultation of the sun by a planet, etc. – or celebrations of historical events, birth anniversaries of famous scientists, of important scientific discoveries, or of the annual National Science Day, instituted in 1987. Such programmes generally include one or more of the following: popular lectures, exhibitions, debates, competitions, essay writing contests, quiz programmes, and the like. These are generally interesting and informative activities alright, but do not amount to much in terms of any lasting impact on the audience.

Let us look at the ongoing science communication efforts in the country, in terms of the sections of our population that are being reached, and with what frequency. Such efforts can be roughly divided into two categories: One, where visitors to venues of science centres, science museums, and planetaria (almost all located in big or moderately large cities) make up the audience; and two, where activities and programmes are conducted at different places (both urban and rural) around the country, almost literally attempting to take science to the people. Some of these programmes/ activities are:

* long duration theme-based campaigns
* specially made serial radio and television science broadcasts
* large-scale field programmes like the Bharat Jan Vigyan Jatha (BJVJ) of 1987 [1]
* science fairs
* annual children's science congresses conducted, since 1993, with the help of voluntary agencies and their networks, all over the country
* the outreach activities conducted with the help of mobile vans

In category one, a very large proportion of the audience is made up of school students brought in organized groups and batches, the rest being tourists and those belonging to the urban middle-class who can afford to pay for transport and entry fees, and use their visit as an occasion for a family outing. In category two, also, school students do form part of the beneficiaries, but the much larger proportion is of the general public, of both the urban and rural variety – and this is especially true of the audience for radio and TV broadcasts of science serials – and those reached via projects like the BJVJ.

For any communication to succeed with a given audience, the message or information to be conveyed has to be delivered to the audience, repeatedly and simultaneously, in many different and interesting ways. Additionally, if a way can be found to make the audience participate in activities where the same message/information is being applied practically, it would enhance the chances of retention of the desired information by the audience. Such a recipe is of particular importance in science communication, for, along with a high level of retention, the correctness of the information conveyed is crucial.

Close attention needs to be paid to the formulation and design of the essential content of the message or information to be delivered. This will depend on the audience itself, as also the medium and mode to be employed for delivery. If the content designed can match sensitivities, sensibilities and interests of the audience, the receptivity and retention levels are likely to be enhanced, increasing chances of successful delivery. But even with all this, communication through mass media necessarily and largely are one way, non-interactive and sans any audience participation, limiting its effectiveness. However, to a certain extent, effectiveness can be enhanced by using innovative software design, media-mix, and mode of delivery. Good examples of this are two highly successful and acclaimed weekly radio serials, *Vigyan Vidhi* (1989) in 13 parts and *Manav Ka Vikas* (1991-94) in 130 parts, jointly produced by NCSTC and All India Radio and broadcast by the later from all its stations (barring Vividh Bharti commercial stations), spread around the country, numbering well over 120. To supplement and complement the weekly broadcasts, specially designed charts and do-it-yourself kits (one each for every 3-4 episodes for *Vigyan Vidhi*, and a smaller number in the case of *Manav Ka Vikas*) were provided to all registered listeners – 140,000 children of 10-14 years, for *Vidhi Vigyan*, and over 100,000 children (again 10-14 year olds) and 10,000 schools for the *Manav Ka Vikas* serial. In each case, there were built-in episodes (roughly once, every month) to answer listeners' queries. Please see Note [2] for more details.

With whatever we have on the ground, in terms of 'science communication' infrastructure, in the country, it is highly unlikely that, barring school students, many in the audience being reached are getting multiple exposures. Multiple exposures (to the right type of science communication) would help the audience retain, supplement, and reinforce knowledge and awareness picked up during their very first, or later, exposures. Those who do, do so courtesy their ready access to the printed word (newspapers, magazines etc.) and/or the electronic media, i.e. radio, television and the internet. Many school students, too, get to do so via their class room, or other co-curricular activities in most of the private, and some of the government, schools, or at home, via radio, television and the internet. Unfortunately, there is no dedicated TV channel for science in India, which could supplement, complement, support and reinforce science communication efforts being made in the country. This is not to undermine, or belittle, the excellent science programmes one often gets to watch on channels like the National Geographic, Discovery and the Animal Planet. They are also quite popular, and being watched by a good number of Indians. They, however, can not fill the gap that needs to be filled by a dedicated Indian Science channel. If all the Indian institutions engaged in science communication in India were to pool their resources to set up a TV channel dedicated to science, and attuned to supplement, complement, support and reinforce their efforts, they will find the outcome well worth the effort.

Meaning of Social Upliftment

How now do we relate all this to 'social upliftment'? To answer that, we first need to understand what this very general term means. Social upliftment could mean a lot of things; in fact, different ones to different people. 'Social' according to one dictionary means: of, or relating to society or its organization; concerned with the mutual relations of human beings or of classes of human beings; living in organized communities. According to another dictionary, 'social' means pertaining to or concerned with human beings and their relations to each other; of, or dealing with living conditions, health, etc., of human beings.

Viewed in this light, 'social upliftment' would generally mean improvement in the living conditions of the common people, including their health of course. In the Indian context, it is our people living below the poverty line, who need social upliftment the most. They suffer from most of our perennial problems arising out of insufficient, or inadequate, food, clothing, and shelter; poverty, illiteracy, unemployment, lack of sanitation, access to safe drinking water and medical facilities; and discrimination on grounds of caste, gender, and religion.

We need to be more specific and, of what has been described above, see what can be effectively and meaningfully addressed using science communication. Notwithstanding, what has been stated above, a very simple way of understanding what 'social upliftment' means is to view it as transformation of 'have-nots' into 'haves'! On the face of it, this appears to be a simple and rather neat idea: divide the whole population into two groups of 'haves' and 'have-nots'. At any given time, there is an ongoing two-way movement of people between the two groups, i.e. some 'haves' becoming 'have-nots' and some 'have-nots' turning into 'haves'. Effective social upliftment would imply accelerating one of the movements and decelerating the other so effectively that there are none left in the 'have-not' category. Thus, converting 'have-nots' into 'haves' is 'social upliftment'. But the simplicity and neatness of this idea disappears as soon as we try looking into what makes one a 'have-not'. It is not one, but a whole host of things, ranging from food, clothing and dwelling; to illiteracy, poverty and unemployment; to depravities of various kinds arising out of discrimination based on caste,

creed, religion, physical disabilities, certain medical ailments, and more, which contribute to the making of the 'have-nots'. That would have been alright, except for the fact, that 'haves' in one category could be 'have-nots' in one or more other categories, and vice-versa. Examples: A person, otherwise qualified, may not get a job, merely because he/she was born into a so-called scheduled caste, scheduled tribe, or a particular religion. So a person who is in the 'haves' category as far as education is concerned, would be a 'have-not' employment-wise. A woman may face discrimination in matters of employment in certain jobs, or promotion, and so on, merely because of her gender; an individual, afflicted with the AIDS virus, may not get treatment at hospitals, beside being treated as a social outcast, even by members of his/her own family. In many communities a child may be nutritionally, educationally and otherwise deprived merely because of her gender. There are countless other examples.

Empowerment and Motivation through Scientific Literacy

It has already been mentioned what science communication is capable of, if done right and properly. It can make one aware and knowledgeable of facts, things and explanations one never knew before. But leaving it at that is like doing only half of the job. Communication ought to continue, persistently reinforcing it with what and how this new knowledge and awareness can bring tangible benefits, if made use of, in appropriate situations – as brought out through real life examples. Such effort should be sustained till the newly gained awareness, knowledge and skills start being put into use in real life by the audience.

Done properly, as described above, one could set a primary goal for all science communication efforts: To equip every one in the population with what we may call "Minimum Science for Everyone (MSE)" [3]. MSE, clearly, would have to have three essential components: (i) Acquiring knowledge of certain scientific principles and facts, i.e. a "minimum science" package; (ii) internalization and application of the method of science; and (iii) acquiring the ability to continue to learn forever. Incidentally, MSE also points to a definition of 'Scientific Literacy', i.e. any one equipped with knowledge and application of MSE would qualify to be considered "scientifically literate".

A scientifically literate citizen is likely to keep him/herself more aware and better informed about matters/issues/events/questions/everyday happenings with scientific and/or technical contents or aspects which concern or relate to his/her everyday life (health, education, employment, housing, food, drinking water etc.) and security; and those concerning/relating to his/her family, community, city, state, and country. In addition, a scientifically literate person, among others, is likely to be:

(i) better placed to critically examine and analyse pros and cons of issues with scientific content;
(ii) a better participant in debates on issues concerning science and technology because of informed opinion(s);
(iii) better able to appreciate technological advances and to make use of them to his/her advantage;
(iv) less inclined to take things for granted and more inquisitive and in the habit of asking questions;
(v) less affected by superstitions and blind beliefs;
(vi) better able to differentiate between fact and fiction;
(vii) better able to argue his/her case on an issue of importance; and
(viii) more confident and self-assured in any discussions.

For science communication to equip an individual with the aforementioned MSE, there is a crucial component which needs elaboration, i.e. "internalization of the method of science (MOS)". MOS is all about finding answers to questions, solutions to problems, explanations for natural or other phenomena, unraveling of mystery and more. It is the methodology used in the practice of science, which is subject to logical reasoning, objective and transparent; its results are interpreted without bias; are made available through publication, including all the details and underlying assumptions, and are reproducible, by others willing to go through the same process. For all practical purposes, it involves core physical (and mental) operations of "observation", "hypothesis", "prediction" and "experiment" (to test the prediction), applied together cyclically till we arrive at the correct hypothesis which provides answer to the question we started with.

Coming to what "Internalization of the method of science" means, it will be easy to understand this if you can recall what you went through in learning to ride a bicycle, or drive a car. You know you can't learn any of these by watching others doing it in person or in a video film, or by listening to someone lecturing on how to ride a bicycle or drive a car. For the former, you would have to get on a bicycle and try to learn by actually doing it. In the process, you may fall a couple of times and get a few scratches on your arms or legs. But once you have learnt how to ride a bicycle (or to drive a car),

it becomes an integral part of you – i.e. gets internalized by you. After learning, and some practice in actual traffic, riding a bicycle (or driving a car) will come to you so naturally. In the same way, you can internalize the MOS by first learning to use it, and then apply it by practicing it on 'solving' a few actual real-life problems. Thereafter, applying it to any and all kind of situations will come to you so naturally.

From this elaboration, we know now the kind of 'science communication' we need to put the audience through, to equip them with the MSE. Equipped thus, as defined already, people who become "scientifically literate" would already have acquired a trait which can be their stepping stone to 'social upliftment'. Practice, it is said, makes one perfect. Likewise, the practice of the MOS, in more and more real-life situations can provide one the needed empowerment, and every little success the needed motivation for the next bigger success – to lift oneself out of the 'have-nots' category and move into the category of 'haves'. A woman, equipped with the MSE, once she is empowered and enabled to lift herself out of the have-nots into the haves, can help others do the same (via the multiplier effect). Others, thus equipped and transformed, can do the same. And once empowered thus, and having tasted success, it is unlikely any of these new 'haves' would ever allow themselves to fall back into the 'have-nots' category.

Notes

1. Bharat Jan Vigyan Jatha (BJVJ) of 1987: A unique communication event conceived, catalysed, and supported by the NCSTC and executed by 26 voluntary organizations, from all over the country. Highlights: (i) Zonal Jathas started simultaneously from Madras (now Chennai), Malda, Solapur, Imphal on October 2, 1987, and on October 3, 1987, from Srinagar, culminating in a rally at Bhopal on November 7, 1987. (ii) Together, these Jathas covered 25,000 Kms, with over 500 halts, through 446 districts and almost all States and Union Territories. (iii) Key themes: Self-reliance, National integration, building a Peoples' Science Movement. (iv) Stressed communication in local languages. (v) Communication means employed: Exhibitions, slide-shows, popular lectures, film-shows, street plays, S&T toys/models/kits, aero-modeling, sky-watching, quizzes, contests, competitions, songs, dramas, organized by over 500 local organising committees spread across the country, prior to and during the Jatha period. (vi) These events were covered extensively by All India Radio, Doordarshan, University Grant Commission's Media Research Centres, the Central Institute of Educational Technology of NCERT, and the Films Division. (vii) The Regional press covered it very well and far more extensively than the national press. (viii) Reached an estimated 70-80 lakh people directly, and many times more through the mass media, and (ix) Identified more than 500 groups throughout the country eager and interested in taking the message of science to the people.

2. Both these serials were broadcast simultaneously in 18 languages from different AIR stations – for instance, in Malayalam from Thiruvanantapuram, in Tamil from Chennai, in Telugu from Hyderabad, in Kannada from Bangalore, in Punjabi from Jalandhar, and so on. The charts and manuals for do-it-yourself kits were also provided to registered listeners in their own local language. The charts gave additional information to supplement and complement the content of the broadcasts. The kits gave them an opportunity to do something with their own hands, to engage in activities which helped them understand and be able to apply scientific methodology in things they could do with the help of the kits. By answering questions asked by kids in response to the serial broadcasts, an attempt was made to make these into interactive programmes in which the audiences (i.e. the listeners) were able to participate in some way. At the conclusion of the serial, quiz contests were held to do a follow up on what the audience had learnt in terms of the key concepts that were sought to be communicated.

Reference

This concept of "Minimum Science for Everyone" or "Scientific Literacy" – was presented by the author in a concept paper prepared for UNESCO, under its Participation Programme of 1998-99, on Promotion of Scientific Literacy & Culture. This concept paper also had an annexure which gave details of the suggested contents for a "Minimum Science" package. A few copies of this document may still be available with Vigyan Prasar, C-24, Qutub Institutional Area, New Delhi-110016.

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Three Phases of Popularization of Science in Colonial Bengal

Chittabrata Palit

Rammohan Roy and Popularization of Science

Raja Rammohan Roy, Father of Indian Renaissance, was also the fountainhead of Popularization of Science in India. This stemmed from his inherent spirit of rationalism.

It was he who wrote the letter to Lord Amherst in 1823 praying for allocation of Rs.1 lakh earmarked for native education, for the purpose of the promotion of Natural Science. He argued that India was already well up in logic, philosophy and literature for material improvement. She badly needed the knowledge of science. The money could be spent for running courses in physics, chemistry, mathematics and life sciences; well equipped laboratories should be set up and qualified teachers could be brought from England for instructions, but the Government did not pay heed to his appeal. It was a cry in the wilderness. But Rammohan was dauntless; he himself wrote scientific treaties on geography, astronomy and geometry for the School Book Society around 1828. In 'Sambad Kaumudi' published by him in 1820, he wrote such marvellous scientific essays in Bengali as 'The Eyes of the Fish', 'Light of the Stars', 'Echo', 'Property of Magnetism' and 'Description of a Balloon'. He made a nationalist critic of the precepts of Jesus and wrote scientific treaties on monotheism. He rationalized Hinduism in the form of a new creed to be called Brahmism and published the essence of the Upanishad. Thus he set the scientific temper of the age.[1]

Dr. Mahendralal Sircar

The Second phase of popular science begins with Dr. Mahendralal Sircar. He was the founder of the Indian Association for the Cultivation of Science in 1876 and through this institutions he propagated popular science.

The Constraints of Colonial Science

Dr. Mahendralal Sircar, the doyen of cultivation of science in India was born in 1833, the year of Raja Rammohan Roy's death. Mahendralal was truly the torch-bearer of Rammohan. He implemented what Rammohan advocated for scientific education in 1823. The pursuit of science and technology during his time was completely in colonial interest and had very little to offer to Indians for their indigenous aspirations and needs. The Asiatic Society (1784), Botanical Gardens (1787), Agri-Horticultural Society (1826) and the Medical College (1835) were all institutes of science but their main objectives were to acquire knowledge about Indian land and people, flora and fauna, religion and culture, health and hygiene to be used as inputs for better colonial administration and extraction of wealth. Michel Foucault in his Archaeology of Knowledge and Order of Things has marked out the evolution of various disciplines because of social and state requirements.[2] The colonial government in India also carried out various official surveys starting from land and land revenue survey to geological and anthropological surveys during most of the nineteenth century. All these surveys involved considerable science and technology but this was not reflected in the syllabi of the government schools and colleges. The later were the strongholds of humanities. Medical education was promoted mainly for the healthcare of the ruling class, and the hospitals mainly catered to them. Rammohan had noticed all these developments and on 11th December 1823, he wrote his famous letter to Lord Amherst pleading for scientific education. The Government had then decided to spend Rs.1 lakh for improvement of education, and the Anglicists and Orientalists fought bitterly over its allocation in their respective areas of interest. Rammohan in that letter strongly opposed the establishment of a Sanskrit College and promotion of Sanskrit learning with this fund and strongly recommended its spending for studies in mathematics, physics, chemistry and other natural sciences with the help of duly qualified staff, suitable laboratories and books. He was not against Sanskrit lore but he thought that India was well equipped in this branch of study and needed scientific education which it totally lacked.[3] But Lord Macaulay's Education Minute in 1835 decided educational policy and expenditure in favour of humanities and English education. The new course had only elementary science in it. The colonial government had no intention to make India self-reliant by training Indians in science and technology. England had already staged Industrial Revolution and therefore wanted India to consume her manufactured goods and supply raw materials to her factories. Shivnath Shastri in his *Ramtanu Lahiri o Tatkalin Bangasamaj* (Life and Times of Ramtanu Lahiri) clearly exposes the elementary level of scientific instruction at the Hindu College. He describes how Dr. Tytler, Professor of Chemistry was nicknamed Soda Sir by his students for whiling away his time on explaining the properties of soda.

But the Government was not alone responsible for it. The elites of that time also wanted to learn English alone and delighted in reciting from Shakespeare, Milton, Byron and Shelley. This was their passport to official patronage and ultimate employment. The scientific temper was sadly missing.[4] Mahendralal passed the Matriculation Examination from the Hare School with scholarship in 1849 and entered the Hindu College which had the same Anglophile ambience. The scientific and mathematical genius of Mahendralal could not be satisfied with it. He left the college after a few years to the surprise of his classmates and despair of his teachers and well-wishers to join the Medical College in 1855. The Medical College had genuine research-based science curriculum in those days. It has well here, he obtained LMS in 1860 and MD in 1863, second after Chandra Kumar Dey, the pioneer.[5] He could have obtained at best the post of Sub-Assistant Surgeon in the Public Health Department on merit. The famous pioneer of dissection and medical practitioner Pandit Madhusudan Gupta could not proceed further than this in his career. The Indian Medical Service was the monopoly of white physicians. Mahendralal, therefore, did not join this subordinate service and set up his own practice instead to become its topmost practitioner. Of the England returned medical graduates, Dr. Surya Kumar Goodeve Chakraborty took the initiative of setting up a branch of the British Medical Association in Calcuta. Mahendralal first became its member and later its Vice-President. In his first lecture before the Association, he ridiculed homoeopathy as quackery, but surprisingly enough, he changed his opinion afterwards and became an eminent Homoeopath himself. He himself states that he got Morgan's *Philosophy of Homoeopathy* for review from the *Indian Field* and on reading it, he gave up his hostile attitude and became drawn to it. To know more about its practical aspects, he began visiting the chamber of the famous homoeopath Dr. Rajendralal Dutta and was profoundly impressed by his medical success. In 1867, he reversed his earlier apathy towards homoeopathy in a lecture before the British Medical Association and pointed out the uncertainties and insecurities of allopathic treatment. This enraged the famous Allopaths of the day - Waller, Ewert and Surya Chakraborty, and they ganged up against Mahendralal to frustrate him. He himself has described his suffering for the sake of truth. Rumour spread that he had lost his faculty and had become a slave of quackery. He was equating part with the whole. His regular patients lost their faith in him and began leaving. His practice was ruined and he did not get a single patient in the next six months. Even those who used to come for free treatment and medicine insisted on old prescriptions but Mahendralal was indomitable. He launched the *Calcutta Journal of Medicine* in the columns of which he carried on his crusade for homoeopathy. He soon built up his practice in the new field as well. The constraints of colonial science and the hauteur of the wardens of Western medicine moved him to stage this revolt. He began looking out for an institute for independent pursuit of science.[6]

The Nationalist Pursuit of Science

Mahendralal first thought of a National Institute of Science in 1869 and began appealing to the public through various pamphlets, letters to the *Hindu Patriot* and lectures in public meetings. In his first public lecture in 1869, Mahendralal set forth his arguments vigorously in favour of such an institute :

"The kind of knowledge which is best calculated to remove prejudice and the spirit of intolerance from the mind is what passes by the name of the physical sciences. And the reason for this lies in the fact that in the pursuit of these studies there is little room for dogmatism. We are certainly at liberty to advance opinions and hypothesis... but we have no right to urge them as facts until they have been verified so that whoever questions their correspondence with nature can at any time satisfy him by observation and experiment. The world is yet being largely governed by the despotism of traditional opinions... but nowhere is this despotism of traditional opinions more severely felt than in this country. The Hindu religion, besides having in a pre-eminent degree, the grand characteristic of all religions, which is to divorce the mind from the works of God, has besides become through the corruption of successive ages, a heterogeneous medley of theology, philosophy, science, and what not. In other words, a chaotic mass of crude and undigested and unfounded opinion on all subjects, is enunciated and enforced in the most dogmatic way imaginable... While the British nation has a duty to perform towards us, it must not be forgotten that we have no less solemn and sacred duty towards ourselves, imperative patriotic feelings for the land to which we have the honour and the pride to belong. It is true that born in India we have inherited submission to a foreign yoke but it must be our consolation that we have inherited a mind not inferior in its endowments to the mind of any nation on earth ...Though regeneration of the people of India will of course, be the work of time and of favourable circumstances, it is in our hand if we will but have it.

We want an institution which shall be for the instruction of the masses, where lectures on scientific subjects will be systematically delivered and not only illustrative experiments performed by the lecturers but

the audience should be invited and taught to perform themselves. And we wish that this institution be entirely under native management and control. We say this not out of vanity but simply that we may begin to learn the value of self-reliance in matters in which we may do it without any serious risk."[7]

In this lecture Mahendralal wanted to inspire scientific outlook among the masses and with that to eradicate superstition and dogmatism. He fondly believed that this would arouse the masses and make them self-reliant even under colonial rule. In another lecture, Mahendralal stressed the need of a national institution for the specific reason that the colonial government was not willing to impart the scientific education to the masses; I say with deep regret that our government has hitherto afforded no opportunity nor afforded any encouragement to the pursuit of science by natives of this country.

He was worried about the nature of superficial scientific education imparted in government colleges and universities where there was no provision for practical work to support such instructions. The public was ignorant of the applied side of sciences. He, therefore, wanted to set up a normal school, a training academy by natives to provide science as well as scientists for nation-building purpose. Mahendralal got some unexpected opposition from his own countrymen in this regard. The fundamentalist orthodoxy opposed him for fear of subversion of religion and spread of heresy. Mahendralal tried his best to reconcile religion to science in a lecture entitled 'Moral Influence of Physical Science' delivered in January 1891 at the Town Hall. He argued that the two were not exclusive terms. Science was essentially a search for Truth, the First Cause, the discovery of the unity of nature and rhythm of the universe. It made one more moral and godly and aware of the Almighty. This was a fixed tenet for Mahendralal in his private life.[8]

The toughest opposition came from the leaders of the Indian League who wanted science to be utilised for improvement of comforts of life instead of cultivation of general science. They wanted employment of the unemployed and production of consumer goods and a Mechanics Institute to promote both. Mahendralal tried his best to convince them that his proposal was not contrary to his critics' project. If a generation of theoretically and practically trained scientists was not produced, who would train the mechanics of the town and the country? His National Association would train the first batch of scientists of India for national reconstruction. The leaders of the Indian League, Rev. Krishnamohan Banerjee, Shambhuchandra Mukherjee, Motilal Ghosh et al. projected their Albert Mechanics Institute to mark the visit of the Prince Consort and thus to get official support for their new political party. In association with the name of the Lieutenant Governor Richard Temple, the Ghosh-Temple League was notorious during that time. Under the pretext of providing popular science, the League wanted to curry favour with the government to earn political recognition of their newly founded party and sabotage Mahendralal's project of a National Institute of Science. Though some writers have tried to justify the more practical purpose of the Albert Institute, there was no noble intent in their enterprise. In the monster meeting at the Senate Hall in 1876, the great Brahmo orator Keshub Chander Sen and Father Eugene Lafont eloquently argued why the National Institute should be more effective and popular in the long run. The Government finally accepted Mahendralal's proposal and gave it financial and administrative support. Mahendralal had resolved that his countrymen should bear its expenses to make it a national institution. He appealed to the native princes, zamindars and wealthy people and invested his own savings. He got unprecedented response to his call for donation. Joykrishna Mukherjee, Raja Kamal Krishna Deb, Digambor Mitra, Jogeswar Singh, Pandit Iswarchandra Vidyasagar, Maharaja Jatindra Mohan Tagore, Dwaraka Nath Mitra, Maharaja of Patiala, Dwijendra Nath Tagore, Gunendra Nath Tagore, Judunath Mallik, Maharani Swarnamayee and others together raised one lac forty thousand rupees.

Popular Science

We can refer back to the previous debate between Science and Technology in this context of popular science. In that meeting, the President of the Indian League, Rev. Krishnamohan Banerjee said in favour of their Mechanics Institute :

"The first condition was that the proposed college was to be considered as commemorative of the condescending visit which His Royal Highness, the Prince of Wales paid to India and therefore it must bear a name suggestive of that idea. The second was the combination of scientific teaching with practical training... the one being based on a feeling of loyalty which would not be allowed to be interfered with. The other was indicative of desire on the part of their subscribers to help in associating a feeling of personal independence with acquisition of knowledge and the attainment of university degrees and honours. No one could tell the day with greater favour than himself if that scheme could give rise to Indian Galileos, Indian Newtons, Indian Herschels and lead to discoveries of new stars called by Indian names, new theories designated by Indian vocables, new terms couched in

Indian language... Existing circumstances compelled him and his friends to think of utilising the discoveries already made before aspiring after such discoveries."[9]

It is evident that the loyalists were unable to welcome Mahendralal's National Institute of Science and its attempts to become self-sufficient. On the contrary, they wanted to strengthen their political organisation through official patronage by sacrificing the cause of the National Institute. If technical education was the main goal for popular science and sustenance, that would still have been a popular scientific resolution. But it was only a pretext for political aims. Even to promote technical education for bread and butter, Mahendralal's proposed institute was the only way. In a speech on 4th April 1875, he explains it himself:

"One of the greatest obstacles to the introduction of science into our schools and colleges is the paucity of indigenous teachers. Now the institution such as I want with your aid to establish will in time furnish abundance of teachers and thus be a great help to Government carrying out its purpose of diffusing a knowledge of science .... The sole function of the Association will be pure science learning and science teaching apart from all bread and butter .... There is at present a sad deficiency of scientific culture amongst our countrymen, the deficiency as has not been and can never be met in schools, even if the utmost efforts were made by the government for the most efficient teaching of science in these schools. In schools people can never rise to the state of practical workers so as to be able to carry on independent investigations not because of any fault in the psychology of pupils themselves but because such a thing is impossible in *statu pupillaris*........ Now, gentlemen, for want of such men here, Government has to bring out men from England, whenever any necessity arises for carrying on investigations in any subject and even for professorships in its educational institutions. Whether, when our Association will be able to furnish such men, Government will accept their services, I cannot venture to say but then there will be at least no excuse for Government to order out men from England at necessarily heavier expenses."[10]

In other words, Mahendralal wanted to get rid of English instructors to teach pure science or even technology and create our own personnel. In 1876 Rev. Eugene Lafont supported Mahendralal in that historic debate to decide the fate of the National Association thus : "The Scientific Association was not intended to produce Newtons, Galileos and Herschels, though even that was not impossible but its primary object was very different and much more practical... The other Association wanted... to transform the Hindus into a number of mechanics requiring for ever European supervision whereas Dr. Sircar's object was to emancipate in the long run his countrymen from this humiliating bondage."[11]

Rev. Lafont's exposure of Krishnamohan's pretence for popular science and his support for Mahendralal's Association enabled the later to get official recognition of the League at that time. Siddhartha Ghosh in an essay upholding the cause of independent pursuit of technology has played up the League's efforts in this regard and played down Mahendralal's Association as a stumbling block. The above should settle the debate. Mahendralal had not opposed the spread of technical education but had actually worked for its spread in many of his lectures on popular science and writings in the Dawn Society's magazine in his later life.[12]

Popular Science and the IACS

In the draft proposal of the IACS, it was clearly stated : "The object of the Association is to enable the natives of India to cultivate science in all its departments with the view to its advancement by original research and as it will necessarily follow with a view to its varied application to arts and comforts of life."

Mahendralal saw in his own life that except for the medical schools, there was no provision for teaching practical science in any other institution. It was not enough to know the principles and practices of science. One had to work with dedication in scientific research and Indians could do it in keeping with that tradition. In a previous lecture he had already denied that he was trying to set up an association like Sir David Brewster's British Association or Count Rumford's Royal Institute. He pointed out that there was no dearth of scientists in that country and the need was how to accelerate original research and spread science among the masses. He had no such high ambition to set up a parallel institution in the Indian context. But he had firm faith that once established, it could reach that target in time. In the draft proposal therefore some basic sciences were proposed to be taught, i.e., physics, chemistry, astronomy, botany, biology, physiology and geology. Graduates from colleges and especially Medical College were to be recruited to man these departments and specialists were to guide them. Trained in this way, the budding scientists would be able to lecture on their respective subjects and undertake fundamental research. He expected this training to be over within one year and two series of

lectures were to be arranged by them, one for the people and the other for the advanced people. Thus popular science would spread among the masses and it would not be impossible to produce scientists in lakhs.[13]

In the series on popular science, Rev. Lafont alone delivered the maximum number of lectures from 1876 to 1893 on Light and Sound. He gave twenty to thirty lectures each year. Dr. Sircar himself also gave lectures in this series for a long time and his subjects were Electricity and Magnetism. He also lectured on Heat for some years. From the annual report of 1891 it is found that Mahendralal gave twenty lectures on Electricity in that year. Jagadish Chandra Bose also gave lectures from 1885 on Electricity, Magnetism and Heat like Mahendralal. Asutosh Mukherjee also joined in 1887 and lectured on physical aspects of Light till 1890. Kanailal Dey first took his classes in Chemistry. He was succeeded by Ramchandra Dutta, Rajani Kanta Sen and Chunilal Bose. Tara Prasanna Roy took his classes in Inorganic Chemistry for a long time and also started his special classes in Applied Chemistry. These classes helped students to find employment. The famous Geologist Pramatha Nath Bose lectured on Geology for some time but due to heavy engagements in office could not spare much time for these classes. Biology was begun in 1894 and Mahendralal himself inaugurated it. Later Dr. Nilratan Sircar and Banwarilal Chowdhury took over. Girish Chandra Bose started Botany. Students from various colleges used to attend these classes. In the report of 1887, it was estimated that over three hundred students attended these lectures. Rev. Lafont in a lecture in 1881 explained the real purpose of this series on popular science. It was not to enable students to pass their examinations but to inform all about the progress of modern science and bring science within the reach of common people. Mahendralal Sircar reported in 1901 at the Twenty-forth Annual General Meeting that almost a hundred such lectures used to be arranged each year. Members and their nominees could attend these lectures without any fees and the public and the students could also do that on payment of a nominal fee.[14]

Dawn magazine, Dawn Society, Mahendralal and Popular Science

From 1901 till his death in 1904, Mahendralal in more than one lecture bewailed the fact that because of the lack of charitable disposition of his countrymen, neither higher research nor popular science could be effectively undertaken at the IACS. It virtually became a private college for the pursuit of science. To fill this gap, Satish Chandra Mukherjee launched his campaign for the spread of science in the *Dawn Magazine* in 1897. His objectives were to retrieve the heritage of science of ancient India, assimilate Western science, spread science among the masses and encourage technical education for employment. The *Dawn Magazine* was dedicated to this fourfold objective. The great men of that time joined him in this campaign. More than fifty essays were carried by *The Dawn* on popular science and the writers included Prafulla Chandra Ray, Jagadis Chandra Bose, Ramendra Sundar Tribedi, Nilratan Sircar and Sarat Dutta. Dr. Mahendralal Sircar also got involved with *The Dawn,* when the Dawn Society was established in 1902. Lectures on popular science and training in technology went on apace under its aegis. Among the essays on popular science published in the *Dawn Magazine,* the following may be specially mentioned : 'The Material Triumph of Science : Report from The Scientific American', (May, 1897), 'Charles Darwin's Mother Nature' reprint from the Progressive Thinker (December, 1897 and January, February 1898), 'Mind in All Animal Life' (March, 1898), 'Fire Proof Tree' (April, 1889), 'Organic Life and Matter' (September, 1898), 'Molecules, What They Are and How They Behave' (April-June, 1901), 'Liquid Air and Solid Air' (September, 1901), 'The Secret of Long Life' (1901), 'Is Matter Alive: Some of the Latest Researches of J. C. Bose' (November, 1902), 'The New Alchemy' (February, 1904).[15] Three essays by Mahendralal Sircar can be traced in this magazine. These are : (1) 'Educational Value of the Physical Sciences from a Moral Point of View' (September-December, 1901). (2) 'Can Physical Science Enlighten Man as to His Destiny' (1901). (3) 'Wireless Telegraphy : As illustrative of the Progress of Science and its Applications' (July-August, December, 1902). As these were not known to historians of science so far, some specimens are given below:

The first is from 'Educational Value of the Physical Sciences from a Moral Point of View' : "It may be questioned in the very beginning if the Physical Sciences can have any possible value in relation to the moral conduct of persons who are engaged in their study ... ... … a physical science embraces a vast or rather limitable field. This is no other than the whole material universe. But infinite as the field may be the study of it is capable of simplification, and has been simplified. And this simplicity as we shall see is of deep significance. The study of the object under his immediate control in the tiny world we inhabit has enabled man to extend his study of the worlds... to the immensity of space and he finds to his utter amazement that all these worlds own a most intimate kinship with each other."[16]

The following is from "Can physical science enlighten man as to his destiny?":

"The study of physical sciences has opened out to man a vista, wider for both in point of space and of time than that bounded his earthly existence and has thus compelled him to take a larger view of his destiny... It is only by a systematic study of the physical universe which is cognisable by physical sense that he finds the universe a cosmos, a well ordered harmonious whole with the impress of a directing intelligence... the contemplation of the Universe under the guidance of scientific study brings the human mind in contact with a Mind which is like itself but infinitely transcending in all its attributes."[17]

The next excerpt is quoted from Wireless Telegraphy : "The reason, why wireless telegraphy is being made so much of, and it is looked upon as a marvel in these days of scientific marvels is that whereas in ordinary telegraphy messages are conveyed by a continuous wire conducting an actual voltaic current from one station to another, this continuous connecting wire between two stations is absolutely dispensed with in this form of telegraphy. The messages are conveyed across space not by what is called an electric current but by some influence which is electrical in origin."[18]

This account of the life-long labours of Dr. Mahendralal Sircar for the promotion of popular science should end all controversies during his life time over his scientific pursuits having an aristocratic bias. He wanted to train the first generation of scientists for nation-building purpose. It was very difficult in colonial India to become independent scientists. Mahendralal wanted to make it possible. The first generation would train the next generation and in this way India would be having scientists. In a land of handicrafts, common artisans were always available but to improve their skill and standard of production, trainer scientists were needed. For the improvement of theoretical and practical science, Mahendralal wanted to make his institution, the IACS the bedrock. His contemporaries opposed him in the name of popular science without trying to comprehend his purpose, but Rajendralal Mitra and Rev. Lafont understood him and supported him. His dream would be fulfilled. Otherwise Indian artisans and mechanics would for ever be under the tutelage of foreign supervisors, which would be expensive, dependent and uncertain. The IACS succeeded in producing the first generation of scientists. Swadeshi industry rose from the level of carpenters, blacksmiths, weavers and dyers. The IACS spawned the scientists. The Dawn Society and the National Council of Education played their complementary parts and produced the technologists. Besides, the IACS used to arrange at least a hundred lectures each year with and attendance of over three hundred people. This was enough to scientist a generation. Mahendralal himself gave such lectures on popular science for a long period and even towards the end of his life, he continued to write essays on popular science in the *Dawn Magazine.* His work was for the benefit of the people and the country as a whole charged by his intense patriotism and nation-building zeal. He was also the pioneer of popular science.

National Council of Education

In the third phase another Institution took prominent part in popularization of science. It was the National Council of Education founded in 1906. In the formative years it had two bodies, Bengal Technical Institute and the Bengal National College which was devoted to the teaching of the basic Arts and Science. In their separate ways, they contributed much to create a scientific community. The Bengal Technical Institute was renamed College of Engineering and Technology from 1928. This was the breeding ground of exceptional scientific minds. Some of the original papers of the student of CET which appeared in its journal show the depth to which popularization of science had gave in colonial Bengal.

It has already been pointed out in a previous chapter describing the debate over the foundation of the Indian Association for the Cultivation of Science that Rajendralal Mitra despaired of the success of the technical institutes in creating a base of technology for the country. They succeeded only in honing up the native skill of artisans. This was the fate of his own Mechanics Institute. Theoretical Science was thought to be the need of day and citizens of Calcutta voted for Mahendralal Sircar's Indian Association for the Cultivation of Science in preference to the proposed Albert Technical Institute in 1876. Since then the IACS continued to create pool of scientists for national reconstruction. But the IACS did not have programme for technology. This was taken up by the Dawn Society in 1902. Though it had both theoretical and practical courses for technology, it was just a small beginning. It lacked qualified teachers and adequate facilities of a workshop. The Dawn Society soon got merged into the National Council of Education in 1906 in the tumultuous days of Partition and its aftermath. The NCE set up a parallel system of national education in contrast with the Calcutta University imparting colonial education. One of its wings, the Society for the Promotion of Technical Education (SPTE) set up the Bengal Technical Institute which ran separately from the Bengal National College strictly on vocational basis without the surrogate of national education. The BTI became a successful institution attracting talented

teachers and students alike. In 1928, it was transformed into the College of Engineering and Technology (CET). Its history has already been told in the previous chapter. In this essay, it will demonstrate how the CET acted as the catalyst of the transition from technique to technology.[19]

Salmon, in his essay on the advent of technology, has rightly remarked: technology is nothing but technique plus theory. The students of the CET had the fortune to study under illustrious Swadeshi Technologists like F. N. Bose, Sarat Kumar Dutta, Hem Chandra Dasgupta, Hiralal Roy, Baneswar Das, Bhim Chandra Chatterjee, Hem Chandra Guha among others. Their training in both theory and practice of diverse aspects of engineering made them both theoretically sound and practically useful.

A brief resume of their original and substantive writings of various aspects of technology is attempted now with reference to some of their papers published in the journal of CET between 1934 and 1947. The first citation is from 'Wireless Telephony' published in 1934 and written by Sudhanshu Shekar Sinha, a fourth year student of Electrical Engineering. The introduction is quoted below:

Wireless telephony is not so new and almost unborn as is generally supposed to be like its companion art, wireless telegraphy; it began its existence well back in the nineteenth century. Its inception is contemporaneous with that of wire telephone, for Alexander Graham Bell was the originator of both. It is a singular coincidence that Bell, the inventor of the telephone and Morse, the reputed inventor of the telegraph, should each have been among the first to accomplish their respective modes of communication wirelessly. The history of wireless telephony follows very closely that of wireless telegraphy. The extreme sensitiveness of the telephone receiver to small variation of current very naturally suggested its employment as a receiving device in connection with the induction and conductive methods of wireless telegraphy and attempts were made at an early date to accomplish the transmission of articulate speech by these same means. The results obtained however were very meagre; the inherent difficulties characterizing these methods proved to be even greater with the application of telephone principles due to the diminution of energy made necessary by the nature of the process. As in the case of wireless telegraphy, the root of the problem lay in the application of the methods electric radiation.[20]

Sinha then goes on to summarise the experiments so far made of telephony by means of Hertzian-waves tries to access the state-of the-art in telephony by giving his own observation.

In the case of an oscillation generating arrangement which does not produce a perfectly sustained train of electric waves but a series of partially damped wave-trains separated by slight breaks of continuity, the essential condition for success in connection with radiotelephonic work is that the interruption shall not take place at an audible frequency. It is highly probable that the direct-current are method of creating oscillations does not produce an absolutely continuous train of waves, as in the case with a high-frequency alternator but on the contrary, is made up of a great number of groups of almost undamped Oscillations separated by an interval of time, very small even in comparison with the duration of each group.[21]

This theoretical exercise by Sinha is remarkable for a fourth year engineering student. It not only speaks of his command over the subject but his ingenuity at the end. These are the soundings of technology in a country of no such tradition.

The same Sinha wrote another essay in the same year on an emerging area even of today. This was entitled, 'Oil from Coal'. Here is the preamble:

Because of the rapid process of mechanisation of the army and of civilization in general, liquid fuel has become of utmost importance in the present state of inevitable quick march of event. Oil-sources are located at considerable distances from seats of power of different nation, some of which are without any oil-field within their own country, colony, protectorates or mandated area. In peace-time, one can buy oil from other countries but during war, possibility of such purchases becomes a doubtful proposition. So semi-industrial plants for the production of liquid fuel must be kept in running condition to be utilized in case of national emergency. Col. K. C. Appleyard, at a meeting of the Midland Section of the Coke Oven Managers's Association, showed by facts and figures that there is no possibility of these processes for the production of liquid fuel from coal or its gaseous products, yet becoming economic in the true sense of the word ....

There are two processes in trial operations by subsidization for the synthetic manufacture of liquid fuel from coal by treating it with hydrogen under pressure at suitable temperature in the presence of suitable catalyzers and activators. The later obtains the oil from sulphur-free water.

The development of these processes had been possible by the pioneering work of hydrogenation by Sabatier and Senderens and high-pressure technique achieved by Haber and Bosch.[22]

Sinha then goes on to survey the aforesaid theory in detail and make a critique of the Fischer - Tropsch process :

Attention has already been drawn to the fact that the Fisher - Tropsch reaction is exothermic, and one of the problems has been the dissipation of the heat generated by the reaction. Many types of reaction chambers have been tested before the final design was adopted and in the apparatus finally agreed upon, the catalyst is arranged between hollow space through which a steam of water flows which can be regulated to maintain constant temperatures.

The fraction boiling over about 210°C provides an excellent Diesel oil when the dissolved paraffin has been removed. It is found to have excellent combustion properties and gives a clear exhaust even with a considerable overload on the engine, while its high hydrogen content enables it to be used with a better fuel consumption than petroleum Diesel oil. Lubricating oil can be manufactured by a by-product of the Fischer - Tropsch process, by polymerising the fractions containing olefixes with anhydrous aluminium chloride. Alternatively, high boiling tractions, low in olefixes can be chlorinated to produce mono or dichloro-derivative, these oils being subsequently caused to polymerise and simultaneously being dechlorinated by finely divided metallic aluminium. It has now become possible to produce lubricating oils possessing the most varying/properties. They are adjustable to such an extent that lubrication oils suitable for any purpose whatsoever can be produced synthetically.[23]

Sinha once again shows his grip over a post-modern subject of science and has the originality of approach to this subject of the 21st century.

Mention can also be made of another interesting article entitled 'Fuel Injection System' by Jnan Kumar Mukherjee, a final year student of Mechanical Engineering. The following are excerpts from his learned article ...

During past sixteen years the development of automotive Diesel and Oil Engine is progressing considerably. The success of this development has been due greatly to the co-operation of the engine designer, the metallurgist, the production engineer and the petroleum technologist. In its general construction Diesel Engine is almost identical with the Petrol Engine except the combustion system. In Oil Engine, there are two principal combustion systems :

1. Air injection or blast injection.
2. Solic injection (mechanical injection, airless injection or pump injection)

..... Difficulty arises regarding the amount of fuel to be injected during each complete cycle. For example, an engine developing 25 H.P. per cylinder at 1200 r.p.m., the amount of fuel injected .007 cubic inch. This amount of fuel during injection must be filtered well ... In case of Diesel and Oil Engine which operate over large range of speeds, it is essential to vary the point at which the injection of the fuel begins in order to compensate for the ignition lag. Means are provided to allow the point of injection to be controlled, either manually or automatically. The mechanism is usually incorporated in the injection pump housing. Many engineers are provided with a vernier coupling on the injection pump drive shaft to allow a permanent alternation of the point of injection.

In order to obtain easy starting of the cool cylinders, glow plugs like spark plugs are used to heat the mixture. Instead of two electrodes it has resistance wire filament which becomes red hot when the current passes through it.

These are the general equipment of the injection system of the Oil Engine. Every part of this system should be in perfect state so that perfect combustion and consequently the output of the engine will be ensured.[24]

The author was not only aware of the new type of injection system used in the general motor companies; he was trying to suggest improvement on the system in his own original thinking. He was surely capable of manufacturing operational Diesel and Oil Engines.

We come across a scintillating paper on 'Television' by Satyabrata Majumdar, a third year student of Mechanical Engineering. He proceeds lucidly to explain the inner mechanism of television in this way:

The most amazing wonder of the present times which augurs to go a long way toward the welfare of man is the recent invention of the phenomenon of television. Most of us have had the direct experience of working a radio or getting a radio receiver cater songs, orchestra,

speeches etc. to our satisfaction. The performances occur at a spot far away from the radio receiver the function of which is just to catch those things from the air and serve us the same. Likewise, television helps us to see before our eyes speakers, actors etc. making their respective performance which they do at a great distance. It fell to the lot of,-English Scientist named 'Baird' to be the inventor of this wonderful phenomenon in 1925. Let us see how we can position to understand the working of television. if we divide a picture into very small imaginary parts and if a strong ray of light is made to travel through all the parts within a very short time in a dark room what we really see? We see a glimpse of the whole picture as long as the ray of light continues travelling. This contiguity of vision in spite of breaks however short of the successive lighting of the imaginary parts of the picture has been called the 'persistence of vision'. Our eyes continue seeing a thing in front of it for a very short time after it is withdrawn from our view. So, when the ray of light travels through the picture quickly, our eye can see the whole picture. The imaginary parts of the picture are lighted successively by a ray of light. The process is called "Scanning" and the machine used for this is "the Scanner". This constitutes the most necessary element of television.[25]

He concludes :

Nowadays, war pictures are sent through radio in the same way as stated above. This is called "Radio Photo". It has been found possible in recent times to transport a wholly complete newspaper by means of television. May we draw from it that in a not very distant future that world will be able to read an international newspaper which will carry the message of love, unity and facilitate to a greater extent with more development in the technique of 'Television'.

Though Majumdar knew the technology of television, it took more than 50 years for India to launch her own television system due to infrastructural difficulties and political disturbances. But when the time came television sets became a household product is a trice, as the knowledge was on the fingertips of Indian engineers gathered from the early days of CET.[26]

We now turn to our last quote from a paper on 'The Structure of the Atom' by S. Bhattacharyya, a third year student of Chemical Engineering published in 1937 :

Ever since the discovery of the election m 1895 and of the recognition of the fact that it formed universal constituent of all matters, the older ideas regarding the atom as an ultimate constituent of matter which was not further divisible, became unfamable. Now, as the atom contains negatively charged electrons and because the atom is electrically neutral, it must contain positively electricity in some form or other. But what was the nature of the positive electricity which neutralized the negativity, remained for a time a vague surmise physicists began to speculate about the way in which the atom of positive and negative electricity were combined to form the different kinds of atoms. The first suggestion came from the famous Physicist Lord Kelvin and was further elaborated by Sir, J.J.Thompson. They held that the positive electricity was concentrated in a sphere of about the same dimensions as the atom and the electrons were uniformly distributed throughout the sphere.

But the true nature of positive electricity was investigated by the bombardment with high speed positively charged particles (α particles) by Rutherford and his students.

C.R.T. Wilson developed a method by which the paths of these particles might be rendered visible and even photographed; if those particles are made to pass through super saturated water vapour the supersaturation of the vapour is destroyed by them, the molecules of the gas which are encountered by the traversing a particles become ionised and these gaseous ions form the centres of condensation of water from supersaturated aqueous vapour actually becomes visible, when suitably illuminated, as a fine line of mist. It is observed that most of the particles travel in straight lines, which could not be the case if they were deflected from their course by impact with every atom they encountered a few are diverted to some extent and very frequently complete reversal of direction of motion occurs.[27]

This was the height of theoretical exercise by an engineering undergraduate. Artisanal technique had been elevated to a high level of technology. Benoy Sarkar was not far from truth when he asserted that the Jadavpur boys had become avant gardes of industrialisation and modernisation of India. They had successfully assimilated Western technology and enriched it by their own ingenuity.[28]

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Impact of Science Museums and Centres

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Abstract

Science Centres render a valuable service to their communities. As a result of visitor oriented activities, Science Centres have a profound impact on learning, motivation and attitude of a person, on local economies, on social processes and on policy making at official level. Personal impact means enhancing the knowledge or skills of an individual or group; economic impact is a measurable contribution to the economy of the surrounding community; societal impact means any identifiable impact on social processes at the individual or social level; political impact encompasses any influence at the decision making level or in gaining mileage. Science Centers are institutions that offer hands on science learning environment. Science Centres strengthen the motivation of students, and influence learning strategies, attitudes towards science and the career choices of young people. Though many Science Centres run on subsidy, they pay back many folds of the subsidies as personal, social and economic impacts on the local communities as well as enriching public understanding and appreciation of science and technology. Science Centres are among the major tourist attractions all over the world. They are also prime elements in cultural tourism. Millions of people visit Science Centres globally. Science Centres also work tirelessly for physically challenged and underprivileged people and are in constant endeavor to take science learning to distant rural areas. Leaders of the state consider Science Centres as agents for development and social change. Qualitatively, it is easy to understand the impacts of science centres. What we need is the evidence of a long term quantitative impact.

Introduction

A Science Museum or Centre is a public institution. With mission, goal and strategic plan, these institutions rely on funding (government, public or self-generated revenue), and staff for their daily functioning. They produce a large numbers of tangible outputs for clients or visitors such as exhibitions and educational activities and intangible outputs like learning, motivation to do science and socio-cultural influence. In addition, they have strong economic and political implications. These outputs significantly impact the science center's community of interest.

By the turn of the last millennium, there were about 1200 science centres all over the world attracting some 184 million visitors and with a total turnover of US$1.4 billion [1,2,3]. According to the Global Science Center Statistics[4], in 2005 the total number of science centres around the world was 1492 serving to 275.3 million visitors with an operating budget of US$3.6 billion. *Beetlestone et al*[1] have also noted that the average increase in the number of science centres round the globe is about 30 percent per decade. Though there are differences in the survey statistics on science centres, it is clear beyond all doubts that science centres have come in a big way in recent times. In India, the number of science centres in 2001 was 35 and that has grown to more than 50 in 2009; over 25 new centers are in the pipeline or in the process of development. The demand has steadily grown over the years with their existence is being linked to social and community development. However, the pace would be even faster if the growth and development were not restricted by lack of infrastructure creation, inadequate professionals and slow capacity building.

Science Centres provide a significant range of educational, social, cultural and economic benefits to their communities[5]. We now see a new dimension to their relevance i.e., political as politicians take keen interest in their development to project, the activity as significant infrastructure development in their constituencies to take mileage. Science Museums and Centres serve as educational forums and centres of expertise, providing opportunities for community involvement in their activities through friends' groups, volunteers, project work and in other useful ways. Science Centres give support to educational organizations, and offer a facility for educational events and activities in an environment which otherwise is not available in educational institutions[6]. In every sense, science centres and museums enhance the quality of lives of people and can play a key role in developing a sense of identity for the area in which they are located.

In short, the Science Centers provide a medium

* for building up a trust between the public and the scientific knowledge through dialogue, participation, engagement and experience
* to translate a particular scientific information into a fairly comprehensible and relevant mode to the population
* to motivate the public by educating them on intricate scientific topics
* for engaging the general public with scientific issues and play imperative roles in sustaining values in local communities
* to provide a hands-on and minds-on learning environment and support science education programme of educational institutions

* to encourage young audiences to make career choices in science by demonstrating excitement of science and engaging them in true process of scientific enterprise

Various studies on the impact of science centres and the assessment of the extent of the influence of the science/scientific knowledge and understanding implicated by the masses have indicated definite outcomes in terms of personal, social and economic impacts. The political impact predominantly appears to be an Indian phenomenon.

Garnet[7] developed a model based on the description of the impact of science centres described by *Persson*[8]. The impact of science centres could be divided into four main types; personal, societal, economic and political.

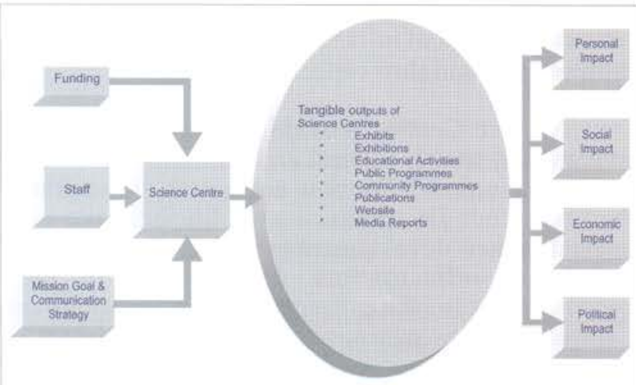

Fig. 1. A Model of Impact of Science Museums/Centres

The **Personal impact** of a science centre is defined as the change that occurs in an individual as a result of his/her contact with a science centre. It includes factors such as:

* Science learning (Cognitive development) through non formal means
* Scope for free choice and lifelong learning
* Development of skills
* Scope for nurturing Creativity
* Changed attitudes towards science or its appreciation
* Social experience, family learning
* Motivation, interest and outlook change
* Career choice formation
* Increased professional expertise through training programmes
* Personal enjoyment
* Adoption of method of science in day to day activities

The **Societal impact** is defined as the effect that a science centre has on groups of people, organizations, and on the community as a whole and natural and social environment. Examples of societal impact are:

* Community leisure activities
* Creating a Science Awareness and development of Scientific Temper in the society
* Community partnerships; involvement of local clubs and societies
* Science Centres as hub of scientific discussion on important issues
* Environmental restoration
* Promote scientific solutions of their local problems
* Enhance employability through skill and knowledge development
* Clarify the scientific issues confronting the community
* Eradication of superstitions or unscientific belief
* Create awareness on health issues relevant to the society
* Promote use of improved scientific practices and technological tools to improve productivity and profitability of the individuals and community.
* Infrastructure development
* Develop into a centre of community activity and symbol of pride for the community.

The **Economic impact** of a science centre is the direct and indirect effect it has on employment and the local economy. It includes factors such as:

* Local/regional/international tourism
* Income brought into the science centre from visitors
* Income brought into community by visitors
* Science centre expenditure
* Job creation for staff (particularly for the youth) and outside service providers
* Urban redevelopment
* Appreciation of real estate
* Business activity develops for variety of vendors serving the visitors
* Demand creation for science education resource material

The **Political impact** of a science center is its influence on government policies and priorities (laws, local regulations, urban planning decisions by municipality etc.). It is its impact on all levels of Government and political leadership who consider and promote development of science centre as an essential parameter of social and regional development.

Personal Impact

The personal impact is mostly in the cognitive, psychomotor and affective domains. In addition, they include fostering creativity, motivation and developing a positive attitude towards science as an outcome of learning, interaction and experience in science centres.

Science Learning

A science centre is a forum which provides facilities for activity based learning process for cognitive development and to inculcate a spirit of enquiry, to develop a positive attitude towards the subject matter, to foster creative talent and to generate scientific temper and build up a self-reliant culture of science in the community as a whole. It is characterized by its two channels of communication-exhibits and activities. The exhibits are interactive and participatory and intended to kindle fire of imagination in a young mind. They encompass a wide variety of subjects such as physical, applied, natural sciences, energy, environment, crafts, industries and such other areas as broadly linked with science to fulfill the

Fig. 2. Learning in Science Centres is activity and participation oriented

requirements of a wide spectrum of population. Activities include year round science demonstrations, shows and training programmes, hands-on workshops, temporary and mobile exhibitions, audio-visual communication, people science movement and similar sort of exposure oriented programmes. The activities are oriented towards the students as well as the community. Science centre experiences are enjoyable, leading to measurable increase in motivation and interest among students for science. The learning is a bonus. Many studies have revealed increase in the range and depth of visitors' conceptual understanding. Commenting on Science Centre learning *Rennie & McClafferty*[9] concluded that "visits to interactive science and technology centers, museums, aquariums and zoos provide valuable motivational opportunities for students to learn science and they affect students' learning." Their studies also indicated that students usually find visits enjoyable but both the extent and nature of their cognitive and affective learning vary.

Free Choice Learning

Free-choice learning is a dominant form of learning in the world; about 60 percent of a person's total learning comes as free choice learning. The culture of school learning is characterized by strict curriculum and evaluation. Science Centres, in contrast, typically impose no such curriculum, and the learning pathways to be followed are normally determined by the learners themselves. Mapping learners' achievements thus depends on recognizing the destinations that are reached along this pathway. It also depends on an understanding that the journey and the destinations are equally significant. Every learner starts and finishes the science center experience at a different point on the pathway. According to *Falk & Dierking*[10] and *Falk*[11,12] science centers may be described as *"free-choice learning environments."* Personal, sociocultural, and physical contexts contribute to and influence visitors' interactions and experiences.

Hands-on Learning

Students in hands-on science programs have been known to exhibit increase in learning and creativity, positive attitudes toward science, perception, logic development, communication skills, and reading readiness. Understandably, *Oppenheimer*[13], while planning for The Exploratorium, was greatly influenced by the philosophy of great American educational philosopher John Dewey. Dewey contented that education should be practical and it needs to be useful in life. It is today the guiding philosophy of most of the Science Centres including NCSM units. *David*[14,15] remarked, "Exhibits and education programs are contemporary, participatory, informal education instruments rather than historic, 'hands-off' repositories of artifacts and they offer the public opportunities to learn in a semi-random web of experiences, facts, lessons and impressions that result in an unstructured and usually undirected accumulation of knowledge." *Bradburne*[16] says, "Science Centers vulgarize knowledge to make it palatable to the masses, or sugar-coat science with gratuitous hands-on interactions to arouse visitor curiosity."

Fig. 3. Hands-on experience with science is a major characteristic of Science Centre learning

To have practical knowledge, one must practise and participate as science cannot be learnt without props. Most educational programmes in a science centre are active and hands-on. The science camps, model making workshops, computer training programmes, creative science workshops, science fairs and teachers' training programmes are aimed at, *inter-alia*, developing practical skills. *Bloom*[17] has categorized the learning into cognitive, affective and psychomotor domains of which psychomotor skill development plays an important role in science centres.

Motivation

Skinner[18] has concluded that a person gains 80-85 percent knowledge mostly by self learning. Learning in science centres is thus voluntary and self-directed. Motivation plays a very important part in science centre learning. Here people learn because they love to learn and not because they are coerced to learn. As the science centres do not follow any set pattern of syllabus, and as the exhibits in the science centres are not sequentially placed, learning is self directed. Thus visitors are encouraged to explore the science centre as if they are in charge, deciding where to go and what to see. Science centres thus create spaces where people can learn independently, safely and creatively. *Csiskzentmihalyi & Hermanson*[19] have called this an intrinsic motivation, but the situational interest developed from the visit to a science centre can act as an external motivation for science learning which comes through three steps: attraction, engagement and ownership. Along with the findings and observations focusing on the attitude toward science learning and career choice there are case studies emphasizing solely on the motivation of school students visiting Science Centers. *Salmi*[20], suggested that the situational motivation of students could be changed to intrinsic motivation by well organized events or programs linking schools to the informal, open learning environments of science centres.

Nurturing Creativity

Creativity is a mental process involving the generation of new ideas or concepts, or new associations between existing ideas or concepts. From a scientific point of view, the products of creative thought (sometimes referred to as divergent thought) are usually considered to have both originality and appropriateness. Fostering creativity is one the most important goals of the science centres. Most exhibits and activities are aimed at that goal. The exhibits, activities like *creative ability camp, hobby camp, science seminar, science drama, quiz, poster design and software development* etc are important examples. Learning in science centres has five dimensions, of which divergent thinking is with the prescription of *Torrance*[21] (5 steps to encourage creativity), science centres always encourage free, independent and divergent thinking in activities such as creative ability camps or science seminars.

Socio Cultural Learning

According to *Vygotsky*[22], a major portion of the learning takes place in the perspective of meaningful activity and social communication. Many people visit science centres in family groups. In such a group, a child does not learn alone; rather he learns by asking questions to his elders and friends and enjoying the exhibits. Through interaction, families have been observed to move from identifying and emphasizing to interpreting and applying their science centre experiences.

Fig. 4. In a Science Centre, people learn together. Here, socially mediated learning is important

Supplementing School Curriculum

Science Centres work directly with schools through in-house and outreach school programs, reaching an estimated 3.5 million school children (25-30 percent of science centre visitors) every year in India alone. Science Centres have an important role in providing education services to users, whether these are children or adults. Some education services will provide a range of formal teaching opportunities in the science centres; others will work closely with teachers to allow teachers to make better use of the educational resources available through displays and exhibitions, databases, handling collections and science centres staff. The

look of wonder on a child's face can be the reward for a lifetime's work in science centres. It is the aim of science centre education to foster contact between people – whether children or adults - and science: not to teach facts, but to sow a seed of interest, a spark of inspiration. The liveliest science centres are not content to wait for people to come and visit them: they take their service out into the community. Similarly, science centres education services are not limited to helping visiting school-children- they include many different ways of taking the science centres out into the schools and into other parts of the community.

Choice of Careers in Science and Technology

A number of studies in several countries have identified an informal exposure to science, comprising visits to science centres, as a major factor in career choice. In India several successful scientists attribute their career choice to their visit to science museums and centres in formative stage of their educational path. A glimpse at the visitors' book of any science centre will reveal that generations of scientists attributed their lifelong interest in science to the childhood visit to Science Museums. *Woolnough*[23] found that extracurricular science activities encouraged students to study science at school and to pursue science careers. While surveying university students in Australia, *Coventry*[24] found that 80 percent of students studying for science-based careers had visited science centres at least once.

Visits to Science Centers Leave Long-term Memories

Learning is "constructed over the years as the individual moves through his socio-cultural and physical world; over time, meaning is built up, layer upon layer," and science centre visits aids as an element of our long-term memory store house. *Stevenson*[25] examined for the influence of a major interactive science exhibition immediately after the visit, a few weeks later, and then after six months. It was observed that even after six months, visitors were able to recall spontaneously the details of their experience. *Beiers & McRobbie*[26] found proof of children integrating the science centre experience into pre and post visit mental models over the course of a few weeks. According to *Reisberg & Heuer*[27], the experiences of the visitors generate powerful emotions which enable the experiences to be more memorable and easier to recall.

Societal impact

Science has become a part and parcel of almost all activities of modern society. It has entered into the fabric of our community life. Knowledge of science having relevance to daily practices must, therefore, must be brought within the reach of every citizen. They must be guided to explain their daily happenings in terms of science and not by superstition and prejudices. They should be made to realize that so called taboos have no value in their life and it is the applications of science that can help solve many problems they face

Fig. 5. Technology access for sr. citizens

very often. What is, therefore, needed is the organization of sustained science programmes for the community people so as to make them understand the values of science and overcome the barriers of social prohibitions and restriction those result from convention and tradition. Many social and voluntary organizations are active in the field. Science Centres too have to be oriented to provide well-planned and well-organized programmes for catering to the needs of community people. The change of mindset, learning of skills and very approach to day to day activities are the evidences of social impact. *Travers & Glaister*[28] put forward that science centres promote "bridging social capital", precisely developing a connection between several communities and groups.

Community Leisure Activities

In the early 1970s Duncan Cameron, motivated by the impact of early science centers, focused the discussion on the institutional change, needed to move from the museum as a "temple" to a "forum"[29]. More recently, *Casey*[30] described the museum "as a forum for debate by offering reflective space in which people can consider issues in context." Traditionally, museums were showcases of curios, which people did not touch but admired and appreciated from a distance. Science centers promoted a different role for the museum with their emphasis on learning through fun and enjoyment. As a major attraction for leisure activities, today's science centers are tough competitors of amusement parks or zoos. This is reflected in number of visitors who come to science centers. Average visitor figures of some major science centers are given in Table 1: